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FAKULTA TĚLESNÉ VÝCHOVY A SPORTU

Efficacy of post-isometric relaxation technique on muscle tissue and its viscoelastic properties after physical aktivity

Master´s thesis

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V Praze dne …………………. …..…………………….

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EVIDENČNÍ LIST KNIHOVNY

Souhlasím se zapůjčením své diplomové práce ke studijním účelům. Uživatel svým podpisem stvrzuje, že tuto diplomovou práci použil ke studiu a prohlašuje, že ji uvede mezi použitými prameny.

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Poděkování

V prvé řadě děkuji PhDr. Petru Šiftovi, PhD. za cenné rady, připomínky a podněty, které mi pomohly při vypracování mé diplomové práce. Za pomoc při přípravě a realizaci experimentu děkuji také Ing. Pavlu Vodičkovi a samozřejmě PhDr. Petru Šiftovi, PhD. Sean Healy, B.A. mi pomohl s konzultací anglického jazyka a za to mu tímto také děkuji.

ABSTRACT

Title: Efficacy of post - isometric relaxation technique on muscle tissue and its viscoelastic properties after physical activity.

Objective: This study is a pilot analytical and comparative study. The first aim of this thesis was evaluation of the effect of post-isometric relaxation technique on properties of muscle tissue after physical activity. The second aim of this thesis is to present a literature review regarding this topic using literature available.

Methods: This study took place in the laboratory of kinesiology at UK FTVS. Six participants were measured prior to Wingate test, after Wingate test and after post-isometric relaxation or rest. Experimental lower extremity was applied post-isometric relaxation technique and the control lower extremity was not. Muscle tonus of the soleus muscle was measured with myotonometric device developed by Šifta. The final data were processed in the special software in Matlab and the obtained hysteresis curves were used for results analysis.

Results: This study had three hypotheses and none of them was confirmed during the measuremets. The first hypothesis pressumed that muscle tonus will increase after the Wingate test, but it was not confirmed and thus further measurements were strongly influenced in the sense that post-isometric relaxation was not applied on a hypertonic soleus muscle. According to the results obtained from the measurements, greater decrease of the muscle tonus or greater increase of the elasticity of the soleus muscle after PIR was not confirmed when compared with the control lower extremity.

Keywords: post-isometric relaxation, muscle tonus, physical activity, Wingate test, muscle tissue, viscoelastic properties, myotonometer, soleus muscle.

ABSTRAKT

Název práce: Efekt postizometrické relaxace na viskoelastické vlastnosti svalové tkáně po fyzické aktivitě.

Vymezení problému: Diplomová práce je pilotní analyticko-komparativní studií. Cílem experimentu je zhodnocení efektu post-izometrické relaxační techniky na svalový tonus po fyzické zátěži a také shrnutí teoretických poznatků týkajících se dané problematiky.

Metoda: Diplomová práce byla zpracována na UK FTVS na souboru šesti probandů. Studie obsahovala tři měření svalového napětí svalu m.soleus na testované a kontrolní dolní končetině. První měření bylo provedeno před Wingate testem, druhé po Wingate testu a třetí měření po aplikaci postizometrické relaxace a nebo odpočinku. Post-izometrická relaxace byla provedena na testované dolní končetině. Měření svalového napětí se uskutečnilo v kineziologické laboratoři na FTVS-UK pomocí myotonometru. Data byla zpracována v programu Matlab a získané hysterézní křivky byly použity pro analýzu výsledků.

Výsledky: V této práci byly stanoveny tři hypotézy. Ani jedna z hypotéz nebyla potvrzena. Wingate test byl vybrán na základě dostupné literatury jako vhodná aktivita pro zvýšení svalového tonu m.soleus. První hypotéza, očekávající tento postup, nebyla potvrzena a tím došlo k výraznému ovlivnění dalších měření. Post-izometrická relaxace tím nebyla aplikována na hypertonní sval. Měřením tak nebylo prokázáno výraznějšího efektu ve smyslu snížení svalového tonu a zvýšení elasticity svalu po aplikaci PIR na m. soleus v porovnání s kontrolní dolní končetinou.

Klíčová slova: postizometrická relaxace, svalový tonus, myotonometr, fyzická aktivita, Wingate test, svalová tkáň, viskoelastické vlastnosti, m. soleus.

CONTENTS

1 INTRODUCTION

Functional problems represent the field of work for physiotherapists and these problems are caused or accompanied by muscle imbalances. Muscle imbalances represent a frequent problem in our population. Increased muscle tension occurs after physical workload, sports performance, prolonged maintaining in static positions or as a result of psychological discomfort. This problem is connected to the prolonged time individuals spend sitting in the activities of daily living, but it occurs also in athletes or physicaly hard working individuals. It is important to perform regular physical activity with appropriate intensity and frequency to obtain all the benefits resulting from physical activity such as prevention of cardiac problems, prevention of obesity but also building muscle mass and increasing fitness. If physical activity is not performed regularly, but infrequently with high intensity, it has a negative influence on health of the person. Lack of muscle mass and lack of muscle strenght of phasic muscles especially, leads to an overload of postural muscles that are not meant to perform high demanding muscle strenght activities. Overload of muscles is connected with increasing muscle tension and / or formation of trigger points. Nowadays, much pressure is put on athletes to improve their performance. Each professional athlete performs the particular sports discipline to the limit of his ability of his skills and constantly faces overload. This situation has as negative effect on health as lack of activity does.

Of the same importance to appropriate and regular physical activity is sufficient relaxation. Relaxation should follow any physical activity to prevent further overloading of the muscles, to prevent injuries and also to decrease psychological tension. There are many variations of relaxation processes such as active recreation, wellness procedures or professional relaxation techniques performed by physiotherapists.

Post-isometric relaxation is one of the relaxation techniques used for decreasing tension of the muscle. It can be applied almost on any muscle in the human's body. This technique is not difficult to perform, but it does require experience to be performed correctly. Thanks to Zbojan, PIR can serve as an autotherapy for patients with hypertonic muscles, when they use gravity instead of resistance provided by the physiotherapist. PIR which was developed by the Czech neurologist Karel Lewit and it is a simple way to decrease muscle tonus in patients, and there is also an appropriate version for autotherapy, therefore such a technique is frequently used among physiotherapists in everyday practice.

The purpose of this thesis is to measure the efficacy of PIR on viscoelastic properties of muscle tissue after physical activity. Interestingly, although this technique is very common, there is not enough literature regarding its mechanism or its efficacy. Viscoelastic properties of soleus muscle were measured on a myotonometric device developed by Šifta. Because myotonometer is a new measuring device, there is no study measuring viscoelastic properties of soleus muscle after post-isometric relaxation yet. In accordance with these factors, I chose the efficacy of PIR on viscoelastic properties of muscle tissue after physical activity as the topic of my thesis.

In the literature review, the theoretical background regarding post-isometric relaxation and theories explaining its mechanism of decreasing muscle tonus will be explored. The methodology section contains a description of the experiment and the results and discussion section presents the results.

2 LITERATURE REVIEW

2.1 Muscle tissue characteristics

It is an everyday experience for most of us to be able to move a particular part of our body when we wish to. The movement is produced by muscles, which are derived from the mesodermal layer of embryonic gem cells. Muscle tissue is differentiated into three types: skeletal (or striated), cardiac and smooth muscle tissue. Further text will be focused on skeletal types of muscle, because it represents the particular muscle type which is the target of post-isometric relaxation (Hamill et al., 2009).

Muscle tissue has its specific properties enabling muscle contraction. These are muscle irritability, contractility, extensibility and muscle elasticity.

Muscle irritability (or excitability) is the muscle's ability to respond to stimulation by a motor neuron.

Muscle contractility provides tension generation and shortening of the muscle when the muscle receives sufficient stimulation.

Extensibility of a muscle is given by the connective tissue surrounding the muscle and also connective tissue within the muscle. It is the ability to lengthen or stretch beyond the resting length.

And the final one, **muscle's elasticity**, will be further described together with viscosity in the next chapter. Both muscle's elasticity and muscle's extensibility are protective mechanisms that maintain the integrity of the muscle and also maintain its basic length (Hamill et al., 2009).

Skeletal muscles are composed of muscle cells, also referred to as muscle fibers. Within each muscle fiber there are tubes of contractile proteins known as myofibrils. These muscle elements contain either thick or thin myofilaments. Thick filaments are composed of several hundreds of myosin molecules, which can be further differentiated on a long tail and two myosin heads known as a cross-bridges. Cross-bridges, situated on the outer end of each thick filament, can bind to actin in the thin filament and form the molecular basis for force generation. Thin filaments are composed of three protein molecules actin, troponin and tropomyosin.

The composition of the skeletal muscle is shown in the figure number (nr.) one. The nonhomogeneous distribution of thick and thin filaments within the sarcomere gives the skeletal muscle its striated appearance (Alberts et al., 2002; Squire et al., 1998; Krans, 2010; Tamarkin, 2011).

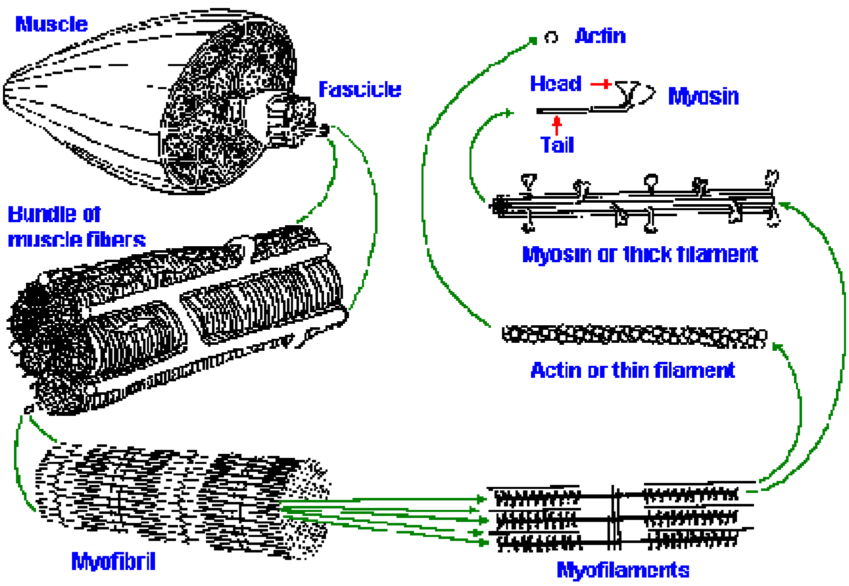


Figure nr. 1: Levels of organization within a skeletal muscle [from http://www.unmc.edu/physiology/Mann/mann14.html]

2.1.1 Viscoelastic properties of muscle tissue

Viscoelastic properties of muscle tissue can be characterized as a combination of both solid and fluid-like behavior. To describe viscoelastic materials a mechanical model of elastic springs and viscous dashpots can be used. Elastic springs represent the elastic behavior of muscle tissue, and viscous dashpots describe the fluid-like behavior. In viscoelastic material, the stress-strain curve is not strictly linear. The combination of viscous and elastic properties indicates the magnitude of stress under specific rate of loading or under specific velocity of the applied load. In this material the stored mechanical energy is not completely returned after the applied load is removed. According to Šifta (2005), viscosity and elasticity are parameters of the muscle that can be reliably measured by a myotonometric device (Gavronski et al., 2007; Hamill et al., 2009; Zhang, 2005; Korhonen, 2005).

Elasticity is the property of muscle tissue to restore its initial shape after contraction or deformation caused by external forces. In elastic materials, there is a linear relationship between stress and strain that defines the stored mechanical energy to be fully recovered. The material returns to its resting length as long as the material did not reach its yield point (Grama et al., 2001, Hamill et al., 2009; Leake et al., 2004).

Elasticity of the muscle increases at muscle contraction with respect to the relaxed muscle ($p < 0.0001$). As the elasticity of a muscle increases at contraction, the mechanical energy is released more efficiently for the movement, with minimum loss for plastic change and thus it may prevent injuries. Low ability of the muscle to revert to its initial shape represents the harder conditions for movement and leads to lesser blood supply during the activity. The higher the muscle's elasticity the better is the condition of the muscle. This finding brings up a theory that elasticity might be a quality resultant of the muscles' functional properties and one can expect that the question how to affect the muscle's ability to restore its shape will become crucial in the field of prevention, rehabilitation and ergonomics (Gavronski et al., 2007; Viir et al., 2006; Veldi et al., 2000, Vain).

The mechanical properties of the cell membrane, especially the fibrous structures of the muscle and the molecular structure of contractile apparatus, were considered as the main source of muscle elasticity. Nowadays, according to the recent studies, it is known that probably the main source of elasticity is titin and nebulin. Both of them create an elastic resistance toward stretching, but titin has probably a greater contribution to elasticity of the muscle (Trojan et al., 2003; Dylevský, 2000).

Titin is a giant protein stored in the sarcomere and it gives the muscle its passive elasticity during extension between Z and M lines of sarcomere. The I-band part of titin is thought to function as a molecular spring, whose elastic properties determine the passive or restoring mechanical properties of the striated muscle (Leake et al., 2004). Bang (2006) mentions that nebulin might bind to the springlike domain of titin. Nebulin is a giant modular sarcomeric protein that is considered as a ruler for thin filament length regulation due to its extension along the entire length of the thin filament.

Viscosity is based on the interplay between water activity and the stiffness of the structure. The relationship between viscosity and water could be explained as viscosity (and stiffness) increases, water activity decreases. Therefore, interplay between water activity, viscosity and stiffness plays a key role in the process of muscle contraction. The water activity coefficient is determined by the sarcomere stretching, by the cross-bridges attaching and detaching and could also be altered by the formation of the network of filaments (Grazi et al., 2010).

2.1.2 Sliding filament model of contraction

2.1.2.1 Sliding filament theory

Sliding filament theory explains muscle contraction and muscle force production. During muscle contraction the thick and thin filaments do not change their size. However sliding of the filament past each other causes shortening of both the entire length of the sarcomere and the length of the muscle. The shortening of the sarcomere can be seen in the figure number two. The length of sarcomere and the zones within each sarcomere are determined by the positions of the thick and thin filaments. The A-band of sarcomere has been considered not to move during contraction, thus myosin filaments remain central and the other parts of sarcomere, mainly I-band, shorten (Squire et al., 1998; Krans, 2010).

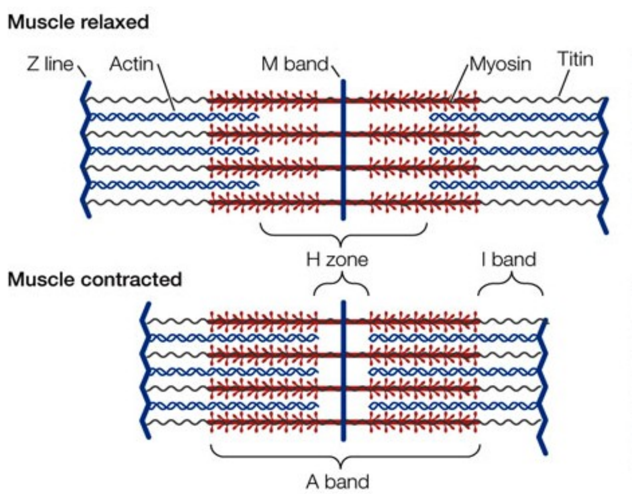


Figure nr. 2: Sliding filament mechanism of skeletal muscle [from http://bcs.whfreeman.com/thelifewire8e/pages/bcs-main_body.asp?v=category&s=00010&n=47000&i=47010.01&o=%7C99000%7C&ns=0]

2.1.2.2 Cross-bridge theory

The model of actin-myosin interaction kinetics, formulated by A.F. Huxley (1957), describes two states, where cross-bridges are either unattached (and not force producing) or attached (contributing both to force and to stiffness). According to the cross-bridge theory, sliding is provided by the binding of myosin heads to actin and also by rotation of the myosin heads. According to the cross-bridge theory the generated force is assumed to be proportional to the number of cross-bridge linkages formed at that time. The probability of formation of linkages is assumed to be propotional to the speed of shortening. The slower the movement, the greater the probabilityof formation is (Mijailovich et al., 1996; Mann, 2008).

The cross-bridge cycle

As it was stated above, the binding of myosin heads to actin is very important for the force production of muscle cells and thus for movement. The process of binding, termed the cross-bridge cycle, includes several steps that are repeating. Each step of the cross-bridge cycle includes a series of substeps that involve protein changes altering the affinity of the myosin binding to actin, Pi, or ADP (Fitts, 2008; Alberts et al., 2002).

Important to mention is the independency of each cross-bridges from one to another during the cycle. For example, some of them will be bound in the rigor complex, some will be undergoing powerstroke and some of them will be unbound. Because of this mechanism, the muscle contraction is not ratchet-like, but it is performed smoothly. During a maximal isometric contraction the states (d, e, f, a) with stronger binding are thought to be the dominant, whereas during isotonic contraction myosin spends only 50% of the cycle in the strongly bound states (Fitts, 2008; Alberts et al., 2002).

An overview of the cross-bridge cycle is presented in the figure number three.

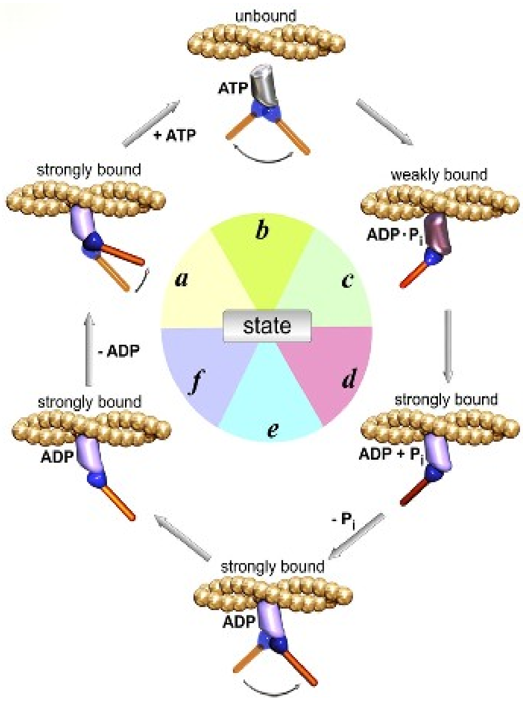


Figure nr. 3: The Cross-Bridge Cycle [Fitts, 2008]

2.2 Muscle tonus characteristics

All of the muscles have a resting muscle tone that can be defined as the tension in resting, the non-contracting muscle, that holds the body against gravity in the absence of external support. According to Cerebra et al. (2004) muscle tonus results from the neural pathways and the central nervous system (CNS). Muscle tonus is also directed by the number of contracted muscle fibres and by the amount of overlaps between actin and myosin myofilaments (Lee et al., 2005; Masi et al., 2008).

Muscle tone is held involuntary and it is controlled by the activity of the stretch reflex. To sustain muscle tone, small groups of motor units are alternatively active and inactive. Having the ability to control muscle tone is imperative. It is essential in maintaining balance, posture and head control, and by varying muscle tone, one can execute fine and gross motor skills efficiently. Appropriate muscle tone enables one to respond quickly to an outside force either through balance responses or protective reactions. It also allows muscles to quickly relax once the perceived change is gone. Postural tone may appear to be rigidly and stably controlled, but tonic activity must be modulated dynamically for movement to be coordinated (Cacciatore et al., 2011; Lee et al., 2006; http://www.atotalapproach.com/docs/PT.pdf).

Abnormal muscle tone is therefore a result of an imbalance between active and inactive motor units, leading to abnormal contraction of muscle fibers. It can be improved in several ways including surgery and drugs. However, physiotherapy is also an effective means to treat an abnormal muscle tone (http://www.atotalapproach.com/docs/PT.pdf).

Hypertonia or high muscle tone is described as an abnormal resistance to passive movement. Hypertonia can be defined as a neuromuscular impairment resulting from increased background motor activity. More specifically, it is a resultant of abnormal excitability of the components of the stretch reflex arc and excessive abnormal and involuntary contractions of muscle fibres innervated by the CNS. If muscles surrounding joints are hypertonic, the joint can not move to its full range of motion and if agonist and antagonist muscles are hypertonic, co-contraction occurs. It results in neither smooth nor efficient movement (Carr et al., 1995).

Hypotonia or low muscle tone is a term for lack of supportive muscle tone. Hypotonia is fundamentally a result of insufficient involuntary contractions and scarce activation of myosin cross-bridges. In hypotonic muscle a limited number of sarcomeres contract to cause contraction and so flaccid muscles cannot generate much tension. It can also be based within the central nervous system, when the complex feedback loops of sensory processing and motor output are implicated (Tortora et al., 2003).

2.3 Regulation techniques of muscle tonus

In this chapter techniques other than muscle energy techniques (MET) and post-isometric relaxation used to regulate muscle tonus such as proprioceptive neuromuscular facilitation and passive stretching will be mentioned. These techniques are considered to decrease muscle tonus as well. In the next chapter a description of MET will be provided.

2.3.1 Proprioceptive neuromuscular facilitation

Proprioceptive neuromuscular facilitation (PNF), the Kabat technique, unlike the MET technique by Mitchell uses a maximal muscle contraction. PNF has various techniques. Relaxation techniques are used to decrease tonus of the muscle, and the contract-relax technique is one of them. During the contract-relax technique maximal isometric contraction of the muscle is performed prior to the relaxation phase. There can be two rationales for the contract- relax technique one is that successive maximal excitations of motoneurons reflexly promote their subsequent inhibition and the second one is that the contract-relax technique works on the basis that a reduction in the H-reflex indicates a reduction in the active resistance to stretching (Wilkinson, 1992).

According to McAtee (2000) a greater range of motion is achieved due to the maximal isometric contraction prior to relaxation phase than from static stretching alone. Also in accordance with Condon et al. (1987) the tested soleus muscle was found to achieve greater gains in the range of motion using variety of PNF techniques than from using static stretching.

According to Wilkinson (1992) the active components are critical in determining the available muscle length in neurologically normal human subjects. The effect of PNF is considered due to active components of the muscle. This can be an explanation for the greater gain in range of motion after PNF, because passive stretching does not involve active components. Also a neurological alteration might occur during PNF because EMG recorded responses indicated a neurological alteration rather than simply an alteration in the viscoelastic property.

2.3.2 Passive stretching

According to Anderson (2009), passive stretching should be regularly practiced for its several advantages such as reducing muscle tension and increasing range of motion. Stretching is said to help in coordination by allowing freer and easier movement and thus it helps to prevent injuries such as muscle strains.

Incorrect stretching includes as bouncing up and down on the muscle or stretching to the point of pain. The correct way to stretch is a painfree, relaxed, sustained stretch with attention focused on the muscle being stretched. The target muscle is firstly stretched until a mild tension occurs. In this position, one should relax and the feeling of tension should subside while holding the position for five or fifteen seconds. Than the particular muscle can be stretched a bit farther, but still it must be painfree to obtain relaxation (Anderson, 2009).

Muscle tone can be changed by passively stretching the muscle, thus practicing the stretch reflex. According to Appleton (1998), it pressurizes the CNS to initiate contraction and respond to the movement. Prolonging the period of stretch causes muscle spindles to habituate which consequently increases the stretch threshold. According to Taylor et al. (1997) the soft tissue react viscoelastically to stretching and it causes a viscoelastic response in the muscle-tendon unit perhaps because of the changes in the connective tissue. However, the role of the neurophysiological and biomechanical component in stretching of human skeletal muscle in vivo remains unclear (Wilkinson, 1992; Magnusson et al., 1996).

2.4 Muscle energy technique

Muscle energy technique (MET) was developed by Fred Mitchell in 1948. It is an effective, non-traumatic manipulative technique used by osteopaths and physiotherapists. Fred Mitchel started using MET to treat dysfunctions of the pelvis and spinal dysfunctions. Its primary goal was mobilization of joint using isometric or isotonic contractions to lengthen a tight muscle, to strengthen a weak muscle or to mobilize joints. Application of MET should relieve congestion in the tissues (Fryer, 2000).

The physiological mechanisms responsible for the therapeutic effect of most manual techniques are controversial and poorly understood. The use of MET is said to inhibit motor activity via the Golgi tendon organs or the muscle spindles (Fryer, 2000).

Chaitow (1999) describes three basic variations of MET the Lewit's technique known as post-isometric relaxation (PIR), the Janda's technique known as postfacilitation stretch and reciprocal inhibition. Description of PIR is presented in the next chapter dedicated to this technique.

2.4.1 Postfacititation stretch

Postfacilitation stretch (PFS) was described by Janda to lengthen chronically shortened muscles. Janda's method is a much more vigorous approach than the Lewit's method and it is used in tight muscles requiring not only relaxation but also legthening of the fascial structures. PFS is a technique of the right choice when there is a contracture due to fibrotic change and not due to disturbance in fuction anymore. During stretching, the actual stretching of the muscle and connective tissue is applied. This method uses a different starting position for the contraction, and also a far stronger isometric contraction than the technique suggested by Lewit. The shortened muscle is placed in midrange position and then patient contracts the muscle isometrically using a maximum degree of effort for five or ten seconds. After isometrical contraction a rapid stretch is made to a new range of motion and held for at least ten seconds. Patient can often feel posttreatment soreness after PFS. Stretch must be maintained for long enough to allow the connective tissue to lengthen accordinly (Uhl, 2008; Chaitow, 1999).

2.4.2 Reciprocal inhibition

Reciprocal inhibition (RI) is mainly used in acute settings, where the usual agonist contraction is precluded by tissue damage or pain. RI is assumed to help reprogram muscle and joint proprioceptors and thus re-educate movement patterns (Chaitow, 1999). It is also commonly used as an addition to PIR (Lewit, 2003).

Muscle is, like in PFS, placed in a midrange position and the patient is directed to push towards the restriction barrier, contracting the opposing muscle. Contraction of the opposing muscle is thought to neurologically inhibit the muscle being stretched and thus to provide a greater range of motion. The therapist either completely resists a movement to perform isometric contraction or allows a movement towards the barrier to perform isotonic contraction. It is also advised to apply some degree of rotational or diagonal movement into the procedure. After the contraction phase the muscle is passively lengthened (Chaitow, 1999; McAtee, 2007).

RI is presented in the figure number four. It refers to a neurological reflex of the inhibition of the antagonist muscle when contraction occurs in the agonist. This happens due to muscle spindles within the agonist muscle fibres (McAtee, 2007).

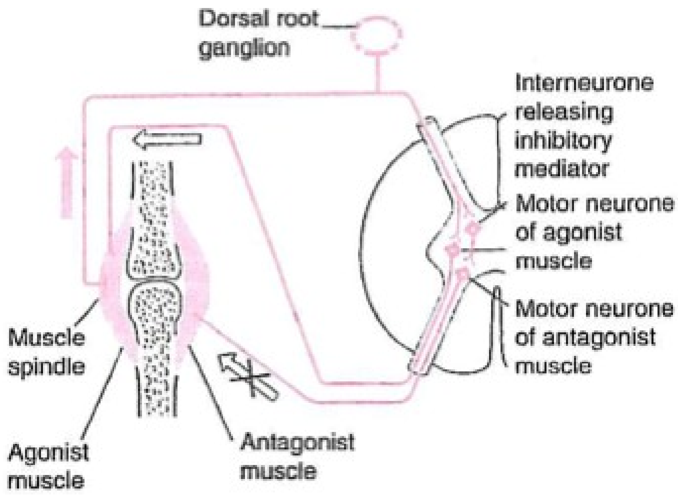


Figure nr. 4: Reciprocal inhibition (http://www.snowdonia-sports-medicine.com/documents/MET.pdf)

2.4.3 Processes involved in muscle energy techniques

The changes within the connective tissues display mechanical properties relating to both fluid (viscous) and elastic components. "Creep" represents the temporary elongation of connective tissue during stretch as a result of its viscoelastic properties. Permanent "plastic" changes occur as a result of micro-tearing and remodelling of connective tissue fibres. MET may produce increased muscle length by a combination of creep and plastic change in the connective tissues. If the relaxation phase in MET would be performed for thirty seconds, it could lead to a prolongation of the muscle due to creep and also due to plastic changes in the connective tissue (Fryer, 2000; Karageanes, 2005).

Venous and lymph drainage is suggested to increase during MET using repetitive light muscle contractions. Muscle contraction and relaxation is a major mechanism for assisting movement of venous and lymphatic fluid (Fryer, 2000).

Inhibition of pain happens as a consequence of joint and muscle proprioceptors stimulation due to movements in joints and isometric muscle contractions. This may cause relief of pain according to the Gate-control theory (Fryer, 2000).

Motor control and muscle recruitment can be changed by stimulation of proprioceptors by muscle contraction. It has been suggested that gentle, precisely controlled spinal muscle contraction, as is used in MET, may increase the recruitment of muscles and help the CNS to improve coordination of the particular region. All these processes may play a role in the therapeutic effects of MET (Fryer, 2000).

2.5 Post - isometric relaxation technique

Post-isometric relaxation (PIR) technique belongs to the muscle energy techniques. PIR was developed by a Czech neurologist, Karel Lewit. The Lewit´s technique is meant to decrease the resistance of muscle towards stretching by decreasing its tonus. PIR technique can be used to treat myofascial pain and or trigger points in muscles, in periosteum or to treat points of referred pain. According to Kolář et al. (2009) PIR can be also used to treat disorders of interstitial connective tissue. Chaitow (1999) considers PIR as a suitable method for joint mobilization. As stated above, Lewit's technique decreases the tonus of hypertonic muscles and thus it represents the close connection between tension and pain, because the decrease of muscle tonus is meant to relieve the pain. In accordance with this fact PIR demonstrates the connection also between relaxation and analgesia (Page et al., 2007; McAtee, 2000; Chaitow, 1999).

Restoring normal muscle tone must first be addressed before attempting to strengthen a weakened or inhibited muscle (Page et al., 2007). The physiologic mechanism of this technique is not clear yet. Although Chaitow (1999) describes the obtained results of PIR to be possibly related to the fact that the minimal force applied during the contraction phase leads only to activation of a very few fibers and the others are being inhibited or to the fact that during relaxation phase, when there is no stretch present, the stretch reflex is avoided. Another two of the most common explanations, based on limited research, are presented further in the text (McAtee, 2000; Chaitow, 1999).

In Lewit's technique, the hypertonic muscle is firstly passively lengthened to its resistance barrier that presents an accumulation of tension in the connective tissue towards further stretching. Subsequent isometric contraction of the target muscle is minimal, using only ten or twenty percent of available strength. This lasts for aproximately ten seconds as the therapist provides matching resistance. The therapist does not want the patient to overpower the therapist. At the end of the isometric contraction phase, the patients inhales deeply and starts the relaxing phase with deep expiration. The isometric phase is followed by the relaxation phase for also aproximately ten seconds or as long as we can still freely move with the extremity. During relaxation phase the therapist moves the limb to the new resistance barrier, until the therapist feels a minimal resistance again, taking up any slack now available, but not stretching the muscle tissue. If the relaxation is insufficient, the therapist can prolong the isometric contraction phase up to thirty seconds. And conversely, the therapist can shorten the isometric contraction phase if the relaxation phase was sufficient. PIR should always be pain free. If the patient experiences pain or discomfort, the therapist should try repositioning the limb or use less force during the isometric contraction of the target muscle. If pain persists, it is not recommended to continue in PIR until the reason causing pain is determited (Lewit, 2003; McAtee, 2000; Karageanes, 2005).

According to McAtee (2000) the correct positioning is very important. To achieve the most benefit from relaxing, the patient should be positioned in that position to isolate the target muscle as much as possible. This isolation ensures that the target muscle is the primary one contracting during the isometric phase and being relaxed during the relaxing phase. Although it is impossible to completely isolate and activate only one muscle, careful positioning does not allow inappropriate compensatory muscle recruitment and helps to achieve optimum results from PIR.

The patient breathes normally throughout the isometric and relaxation phase. Although it is common that individuals hold their breath during any muscular effort and during isometric contraction especially. Another reason is that holding the breath during the isometric phase is often accompanied by compensatory recruitment of other muscles. It is easy to monitor the patient’s breathing throughout the process. Two cycles of normal breathing takes about 10 seconds, which is about the length of time needed for the isometric contraction (McAtee, 2007).

PIR technique can be combined with use of the eye movements. Chaitow (1999) describes that the visual synkinesis facilitates the movements of the head and trunk in the direction of the view and inhibits the movements in the opposite direction. Flexion is enhanced by the patient looking downwards, sidebending and rotation are facilitated by looking toward the side that is relaxing (Lewit, 2003).

PIR is a very common and successful technique among physiotherapist to decrease the muscle tonus although there is always a need for a physiotherapist to lead the resistance and to allow the patient to fully relax during the relaxation phase. Zbojan developed the antigravity method (AGR), which is suitable for autotherapy. During AGR method the isometric contraction is held against the gravity and during the relaxation phase the limb is held in the direction of gravity. It is recommended to prolong both isometric and relaxation phases up to twenty seconds (Lewit, 2003).

2.5.1 The mechanism of post-isometric relaxation technique

PIR technique leads to a reduction of the tone of the muscle. Chaitow (1999) mentiones a latency period of approximately fifteen seconds that is present after the isometric phase. During this period, the movement towards the new position of a joint or muscle can be easier (due to reduced tone).

The mechanism of PIR is not definitely known but there are some explanations about how it is likely to work. There are two main explanations of PIR mechanism which refer to Golgi tendon organs or to connective tissue prolongation.

2.5.1.1 Golgiho tendon organs

The important muscle-tendon unit proprioceptors that provide information on muscle length and tension are muscle spindles and Golgiho tendon organs (GTOs). Stretch receptors called GTOs are located in the muscle tendon junction and react to over-stretching of the muscle by inhibiting further muscle contraction. This is naturally a protective reaction, preventing ruptureof the muscle and has a lengthening effect due to the sudden relaxation of the entire muscle under stretch. GTO works against the muscle spindle, the agonist muscle is inhibited and the antagonist muscle is facilitated by GTOs.

The neurological effect of the isometric contraction on the GTO is presented in the figure number five (Hamill et al., 2009; Knudson, 2003; Latash, 1998; http://www.snowdonia-sports-medicine.com/documents/MET.pdf).

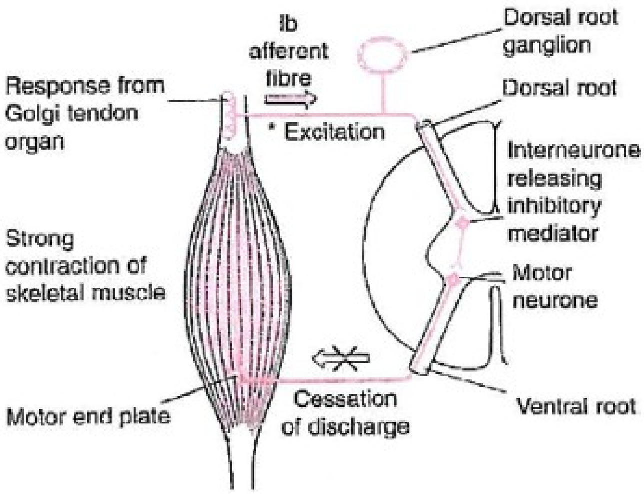


Figure nr. 5: The neurological effects of the isometric contraction on the GTO (http://www.snowdonia-sports-medicine.com/documents/MET.pdf)

Muscle contraction against equal counterforce triggers the GTO. The afferent nerve impulse from the GTO enters the dorsal root of the spinal cord and meets with an inhibitory motor neuron. This stops the discharge of the efferent motor neuron's impulse and therefore prevents further contraction, which results in the agonist relaxing and lengthening. If an active muscle was forcibly stretched by an external force, the GTO would likely relax that muscle to decrease the tension and protect the muscle. GTO is reliable in signaling whole-muscle tension whether it is active or passive tension. With input from upper neural centers, the context changes and circuits are adjusted accordingly (Hamill et al., 2009; Knudson, 2003; Latash, 1998; http://www.snowdonia-sports-medicine.com/documents/MET.pdf).

2.5.1.2 Connective tissue

According to Taylor et al. (1997) a more plausible explanation may lie within the biomechanics of connective tissue. Muscle contraction involves shortening of the contractile element of the muscle, thus greater flexibility following muscle contractions may seem contradictory. During isometric contraction, the force is generated by the shortening of the contractile element. For the entire muscle-tendon unit to remain fixed a compensatory lengthening must occur. Because the tendons of origin and insertion are fixed, the connective tissues must lengthen as the muscle fibers shorten.

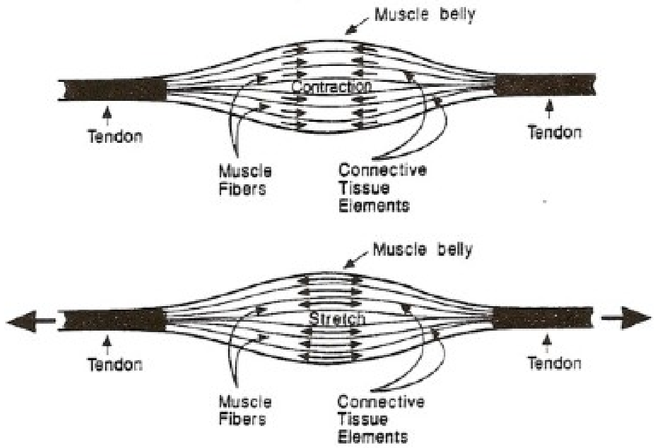


Figure nr. 6: Muscle-tendon unit undergoing an isometric contraction (top) and a passive stretch (bottom) (Taylor et al., 1997)

As can be seen in the figure number six the muscle fibers shorten during isometric contraction, resulting in an elongation of the connective tissue elements and tendons. During a passive stretch the connective tissue elements, tendons, and muscle fibers elongate (Taylor et al., 1997). Fryer (2000) assumes that PIR is mainly a biomechanic process with a combination of release phenomenon due to viscoelastic properties of the connective tissue and plastic changes in the parallel and series compartments of connective tissue of the muscle.

2.6 Isometric contraction of the skeletal muscle

During isometric contraction the muscle increases its tension, but the length of the muscle is not altered. The distance of muscle insertions is not altered either (Jarmey, 2008; http://biomech.ftvs.cuni.cz).

Prolongated isometric contraction of skeletal muscle leads to an increased tonus of the muscle. The rytmical contraction and relaxation of the muscle is needed to support the periperal circulation of the blood. Increased tonus of the muscle affects the capillary network and venous and lymfatic system, where there is low pressure. The arterial blood supply is in the center of the muscle and has higher pressure than the pressure of the drainage of venous blood that is under the surface fascia. During isometric contraction the surface fascia compresses the drainage vein and limits its function. This explains how the prolonged isometric contraction of the muscle deteriorates the conditions of venous and lymphatic exhaust and how it results in the muscle fatique and how it decreases the strenght of the muscle. Over time it causes feeling of pressure, soreness and complete failure of the muscle (Véle, 2006).

The properties of the skeletal muscle during isometric contraction are shown in the figure number seven.

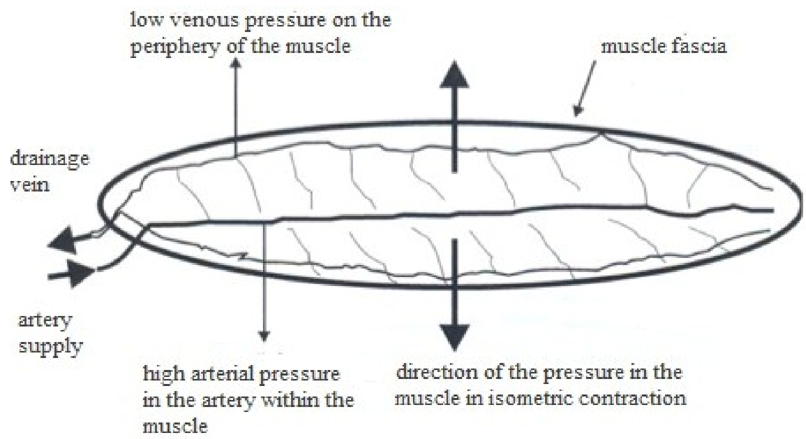


Figure nr. 7: Isometric contraction of the skeletal muscle [translated from Czech language (Véle, 2006)]

2.7 Soleus muscle definition

The function of the soleus muscle is plantar flexion of the foot. At rest, it compensates the anterior decline of tibia and at walk it provides the step movement. The major role of the soleus muscle is to propulse the gait and “grip” the floor during walking (Véle, 2006). The soleus muscle is continuously active during symmetrical standing while it prevents the body from falling forward and thus it keeps the body upright against gravity. This postural role is suggested by its high content of slow twitch muscle fibres, in many adults approaches one hundred percent (Jarmey, 2008; Joshi et al., 2010; Véle, 2006).

Postural muscles can become hypertonic or shortened in contrast with phasic muscles that lead to hypotonia. Thus the soleus muscle has the tendency to become shortened or hypertonic (Lewit, 2003) The hypertonus of the soleus muscle can be accompanied by trigger points superior and inferior in the muscle belly or the referred pain of the heel and or posterior calf (http://www.triggerpoints.net/triggerpoints/soleus.htm; Lewit, 2003). Shortened soleus muscle can assist in forward weight-bearing posture and can limit squatting by keeping heel on the ground (Véle, 2006). In shortened or hypertonic soleus muscles the ankle dorsiflexion is limited. During the test for the soleus muscle, the knee must be bent to ninety degrees to allow the foot to reach twenty degrees of the dorsal flexion. This represents the physiological range of motion reached in non-shortened soleus muscle. When the soleus muscle is hypertonic, one could also observe a muscle hypertrophy in lower muscle calf (Lewit, 2003). The activities leading to hypertonic soleus muscle are excessive running, walking on high heels or ankle instability (Joshi et al., 2010)

For the experiment we chose the soleus muscle, because it is easily reached muscle for palpation and thus for the myotonometric measuring on the dorsal side of the calf. And also because together with scalenni muscles they are said to respond well on decreasing muscle tonus by PIR. PIR technique is used to treat trigger points and also to decrease tonus of the hypertonic muscle and both these indications occur in the soleus muscle.

2.8 Biomechanical aspects

2.8.1 The mechanical properties of relaxed skeletal muscle

According to Podlubnaya et al. (2000) and Muntener et al. (1995), the achievement of the ordered filament structure, representing relaxed state of skeletal muscle, can occur only with presence of ATP and absence of calcium ions. In the relaxed state, tropomyosin might be situated close enough to the myosin binding site either to physically block attachment or at least modify the actin structure in such way that the attachment was blocked. This mechanism is termed the 'steric blocking model', implying that tropomyosin regulates activity by virtue of its position on the thin filaments (Gordon et al., 2000; Squire et al., 1998).

As well as the previously mentioned absence of calcium, the rate of cross-bridge detachments represents another major determinant of skeletal muscle relaxation rate. During relaxation, when calcium concentration is decreased below the threshold for force activation, the regulatory system is completely turned off to prevent recruitment of new force-generating cross-bridges. Cross-bridges slowly transform themselves from force-generating to non-force-generating states and the number of force-generating cross-bridges is considered to involve the relaxation kinetics. Following force decay through increased rates of cross-bridge detachment is accelerated by sudden collapse of isometric sarcomere conditions. The non-uniformity in sarcomere length accelerates the process of relaxation. It is formed by the process of both shortening and lengthening of sarcomere lengths. The shortening is accompanied by cross-bridge detachment and extra calcium ions that dissociated from troponin C. It enhances relaxation because cross-bridge detachment rates are faster when the fiber is shortening than when it is held isometric (Leemputte et al., 1999; Tesi et al., 2002; Gordon et al., 2000).

Herbert (1988) mentioned another opinion that considers intramuscular connective tissue to be responsible for properties of relaxed muscle. The intramuscular connective tissue is organized in three levels: epimysium, perimysium and endomysium. The collagen fibres of the perimysium appear crimped, but when the muscle is lengthened these fibers lose their crimp and the muscle becomes stiffer. The collagen fibers also become more longitudinally orientated.

Relaxed muscle also demonstrates time dependent or viscous behavior under load. It means that the relationship between length and tension changes with time under stretch. Viscous behaviour can be explain as following, if the muscle is stretched to a given length and it is maintained, the tension will decrease over time. "This viscous deformation is probably the major source of the increases in muscle length seen immediately following muscle stretching (p.143, Herbert, 1988)." This viscous deformation was observed to gradually decreased untill the muscle returns to its pre-stretch state. Regarding these facts, the increases in muscle length reached after stretching seem to be a transient phenomena and lasting changes will probably result from an adaptive remodeling of the structure of the muscle (Herbert, 1988).

2.8.2 The effect of muscle length on force developed by a muscle

The force-length relationships predict how much force is the muscle able to develop at its certain lenght. The force-length relationships are said to be dependent on following three factors; on the contractile properties of the muscle fibers, on the organization of the fibers in the muscle and on the arrangement of the muscle around the joint. These factors allow force-length properties to adapt to the functional requirements imposed on the muscle.These architectural factors are expected to have a much greater influence on the muscle function than do the proportions of different types of fiber within the muscle (Balnave et al., 1996; Enoka, 2008).

The amount of developed force in certain muscle length differs, depending on whether the force is developed in maximal or submaximal contraction. Lunnen et al. (1981) stated in his article that according to previous studies, the results refer to a direct linear relationship between muscle length and force of isometric contraction. Two factors are being considered to play a key role in the muscle lenght-force relationship of isometric contraction. They are the active contractile components and the passive elastic components of the muscle (Rassier et al., 1999).

Passive elastic components of muscle have been described as parallel and elastic components. The elastic components are located in series with the active proteins, such as the tendon and protein titin. The parallel elastic components include perimysium, epimysium, endomysium and surround or lie in parallel with the active proteins (Neumann, 2010).

Active length-tension curve is based on the sliding filament theory and the cross-bridge theory. Muscle force is proportional to the number of cross-bridges occuring at the same time (Neumann, 2010).

The amount of developed force in certain muscle lenght differs, if the force is developed in maximal or submaximal contraction (Rassier et al., 1999).

2.8.2.1 Submaximal contraction

In submaximal activation the characteristics of the length-dependence curve of force development differs from activation in maximal contraction. In particular, the peak active tension does not occur at the plateau region sarcomere lenght, associated with maximal overlap of actin-myosin filaments, but it occurs at a longer length. A greater force of submaximal contraction is developed when the number of available cross-bridges is reduced by an increase in muscle length. This property of the muscle has been referred to as a length-dependent activation and is represented by an enhanced activation at long muscle lenghts. The development of isometric tension in submaximally activated muscle fiber is predicted by an average overlap of actin and myosin, free calcium concentration and the force-calcium relationship (Rassier et al., 1999).

2.8.2.2 Force-length relationship of the whole muscle

The connective tissue that combines single fibers into whole muscles is considered to play the major role in the force-length relationship of the whole muscle. This major effect of connective tissue on the force-lenght relationship of the muscle indicates that the exerted muscle force is not solely dependent on the active process of cross-bridge cycling and filament overlap. Although Rassier et al. (1999) describes the lenght-force relationship of the whole muscle to be similar to the relationship of the muscle fibers, therefore the force decreases linearly with prolonging sarcomere lenght, when the myofilament overlap is decreasing.

The fact is that the connective tissue, together with cytoskeleton, exerts a passive force that combines with the active process of myofilaments to create the total force-length relationship of the whole muscle. Considering the total length-tension curve for the whole muscle, the active force is the dominant force generator at short lengths below the resting length. The exerted muscle force rises with increasing lenght of the muscle until it reaches its resting lenght. Resting length represents the point, where passive tension begins to contribute to compensate for the decrement of active force exertion. Further stretching of the muscle beyond its resting length leads to a near-maximal stress of connective tissue, because passive tension dominates the curve (Enoka, 2008; Neumann, 2010; Rassier et al., 1999).

Logically, according to the describtion above it can be stated that the tension is maximal at intermediate lengths and decreases at shorter and longer lenghts. The cooperation of passive and active components allows muscle to maintain high levels of muscle force across the wide range of muscle length even at a point at which active force generation is compromised. The shape of total muscle length-force curve varies in muscles of different structure and function (Enoka, 2008; Neumann, 2010; Rassier et al., 1999).

In the figure number eight is presented the combination of active and passive force that creates the total force-length relationship of the whole muscle.

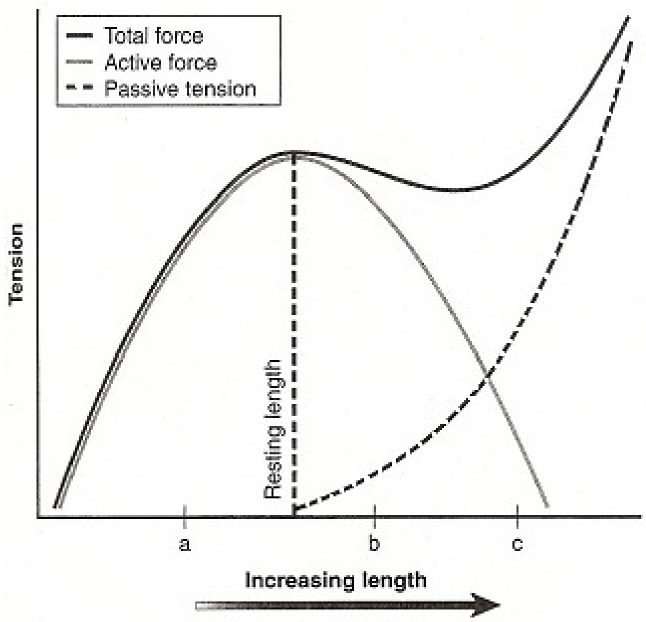


Figure nr. 8: Schema of total and active force and passive tension (Neumann, 2010)

During a maximal isometric contraction the fascicles are found to shorten up to 30% of the initial length. This shortening is accompanied by a corresponding elongation of the tendon and other connective tissue. The change in length of a muscle that occurs when going through the full anatomical range of joint motion is referred to as excursion. Naturally, one might assume that a particular muscle is attached to the musculoskeletal system such that it operates around its optimal length where the muscle exerts the greatest force. However, this situation does not occur, because most muscles have been observed to operate primarily on the ascending or descending region of the length-force curve while reaching the plateau toward the end of the range of joint motion. For example the human soleus muscle operates primarily on the ascending limb of the force-length curve (Enoka, 2008; Rassier et al., 1999).

3 AIMS AND HYPOTHESES OF THE STUDY

3.1 Aims of the study

The aim of this study is to measure the efficacy of post-isometric relaxation technique on viscoelastic properties of the soleus muscle after physical activity using myotonometer and also to present theoretical backgrounds regarding mechanism of PIR using available literature.

3.2 Hypotheses

Hypothesis number one: We presume the muscle tonus to increase after Wingate test.

Hypothesis number two: We presume the muscle tonus of the tested lower extremity to decrease after application of post-isometric relaxation technique.

Hypothesis number three: We presume the muscle tonus of the control lower extremity to be higher than the muscle tonus of the experimental lower extremity.

4 METHODOLOGY

4.1 Characteristics of the study

This thesis is a pilot study comparing viscoelastic properties of the soleus muscle of the two lower extremities of the participants. Six randomly chosen participants were included in this study. Participants represented a homogeneous group for this experiment. There was one group of participants in this study.

4.1.1 Solution of special situations

The personal data of all participants were used only for this thesis and in accordance with law. All participants were informed about this study and gave informed consent prior to the measurements (enclosure number two). This experiment was approved by the ethics committee FTVS UK and this document can be also found attached (enclosure number one).

4.1.2 Characteristics of the participants

All participants except one were students of physiotherapy at UK FTVS. Their age ranged from 22 years till 26 years old. Majortiy of the participants do sports such as jogging or aerobic twice a week for one hour. None of them do sports professionally. The group of participants was consisted of five females and one male. All of them were healthy and without any injury. Neither of them mentioned a knee or ankle problem. None of them had any problem with Achilles tendon and also none of the participants was found to have a shortened soleus muscle. Participants did not feel tired and neither of them was recovering from a disease or was involved in extreme physical activity in the prior two days. No contraindication for the Wingate test, neither for the application of post-isometric relaxation technique was present. All participants were prepared for the experiment.

The group of six participations can be characterized by mean values (x) and standard deviations (s) calculated from participants´ age, weight, height and BMI (table number one).

Table nr. 1: The characteristics of participations

Parameteres / n = 6	x	S
Age	24	1
Weight	69,97	16,38
Height	176,13	9,86
BMI	21,83	2,97

4.2 Data collection

4.2.1 Description of the experiment

The experiment took place in the kinesiology laboratory at UK FTVS. Altogether, the study contained three sets of measurements using myotonometric device. There was only one group of participants in this experiment. The experimental and control lower extremities were differentiated by questioning of the participants. Each participant was asked to identify the takeoff lower extremity that represented the experimental lower extremity. The experimental lower extremity was applied PIR technique and the control lower extremity was not.

The first measurement was after thirty minutes of resting on a chair and prior to the Wingate test. Immediately after the Wingate test the second measurement took place. The Wingate test was performed on the same floor approximately thirty seconds of walk. Heart rate was measured right after the Wingate test and lactate level was tested in the fifth minute after the Wingate test. PIR technique on the soleus muscle of the experimental lower extremity was performed after 14 minutes of resting on the table after the Wingate test. The third measurement of both soleus muscles was measured after PIR technique application or fifteen minutes of resting on the table.

Each measurement was performed twice. All participants finished the experiment. They did not mention any discomfort, nor pain.

Atmospheric conditions in the laboratory during the experiment:

Laboratory of kinesiology: Temperature = 22 °C Pressure = 1021 hPa Humidity = 46 %

Laboratory of load: Temperature = 24 °C Pressure = 1021 hPa Humidity = 46 %

4.2.2 Wingate Test

Prior to the PIR technique application, a physical activity was needed to increase the tonus of the soleus muscle. The Wingate test (WT) was accepted as an appropriate physical activity, because of its high validity and for being considered as the reference standard for the assessment of short-duration sprint performance (Chia et al., 2008).

4.2.2.1 Characteristics of Wingate test

The Wingate test is used world-wide for assessing all-out intensity short-duration sprint cycling lasting between ten and forty seconds at maximal speed and against a high braking force. For this study the original version of the WT was used lasting for thirty seconds. The optimal braking force is 6 W/kg for adult men and 5 W/kg for adult women (http://www.brianmac.co.uk/want.htm; Chia et al., 2008; Smith et al., 1991; Suchý et al., 2007). The Wingate test performance is shown in the figure number nine.

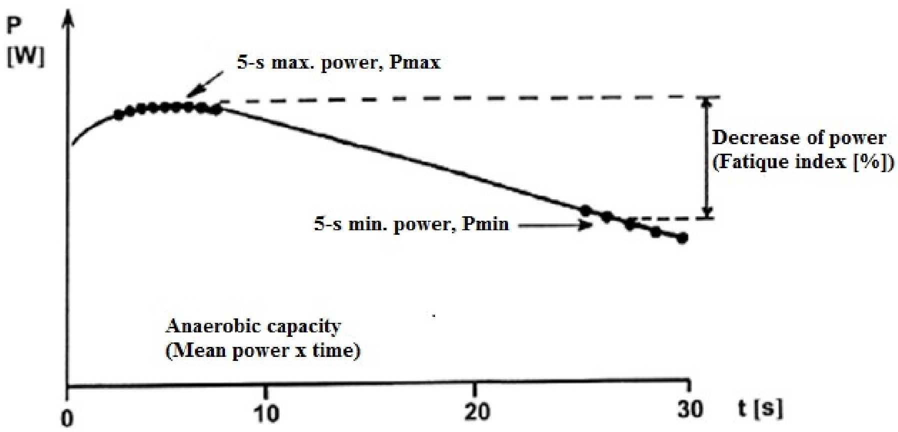


Figure nr. 9: The Wingate Test performance and basic parameters [translated from Czech language; Suchý et al., 2007]

Because the braking force is so high, the participant cannot maintain the initial velocity for more than a few seconds, before starting to slow down. According to Suchý et al. (2007) the maximal velocity is developed in between the third and seventh second of the test. The power peak comes out of the emergency energy sources as ATP, CP or even out of the oxygen bounded in the muscles. The subsequent decrease of the velocity represents the dominance of anaerobic glycolysis in the energy supply, and both the formation of lactate and local metabolic acidosis occurs. In the final second of the test, the velocity is usually on 50-70% of maximal peak velocity. The changes of power output are evaluated in the computer during the particular revolutions or in five seconds intervals in the older version (Suchý et al., 2007). Below is a table number two, showing a summary of energy system contribution throughout the thirty seconds of activity.

Table nr. 2: The contribution of energic systems to the physical activity supply varying time periods and maximal intensity (Suchý et al., 2007).

Time (s)	ATP-CP (%)	Anaerobic Glycolisys (%)	Oxidative (%)
5	85	10	5
10	50	35	15
30	15	62	20

4.2.2.2 Measured parameters

Maximal cycling power is influenced by pedaling rate or fatigue and also by muscle size and its fiber composition. The mechanical power is measured during the thirty seconds by multiplying the force and velocity. The work generated by the subject is calculated by multiplying the power and the time (http://www.brianmac.co.uk/want.htm; Martin et al., 2007; Smith et al., 1991).

There are four indices that describe the participant's performance in the Wingate test. It is Peak Power, Mean Power, Anaerobic capacity and Fatique Index.

• **Peak Power** is the highest mechanical power achieved at any stage of the test. Peak power, or anaerobic power, is the highest power produced in a five seconds long segment of the test (mostly the first) and is expressed in W or Wkg-1'.

• **Anaerobic Capacity (Total Work)** represents the total external work performed in the thirty seconds test and has been used to describe muscle endurance. It is obtained by multiplying Mean Power by zero till thirty seconds, and the units are Joule.

• **Mean Power (MP)** represents the average local muscle endurance throughout WT.

• **Fatigue Index** is the drop in power from Peak Power to the lowest power, and is presented in Watts/Sec. The lowest power usually occurs at the end of the test (http://www.brianmac.co.uk/want.htm; Smith et al., 1991).

• **Additional Indicators -Level of Lactate Concentration** after the physical activity to evaluate the appropriate metabolic reaction to the total work during the testing; **Heart Rate** serves as an indirect indicator of effort during the test (Suchý et al., 2007).

4.2.2.3 Task in the experiment

Each participant was given a sport-tester to monitor the heart rate. A bicycle ergometer was set up according to the height of the participant and data was put in the computer according to his weight to set the appropriate braking force of the ergometer. The braking force was set as 6 W/kg for adult man and as 5 W/kg for adult women. At first the participant performed a low-resistance warm up for five minutes and after was directed to increase the pedalling up to one hundred twenty revolutions per minute. At this point WT started, and the maximal pedalling activity lasted for thirty seconds. Each participant was trying to maintain the velocity of pedalling from the start till the end of the test. The verbal encouragement throughout the test, as well as information about the time left, were both provided to each participant. Right after the WT the heart rate was noted and five minutes later the blood sample was obtained to measure the level of lactate concetration.

4.2.3 Post-isometric relaxation of soleus muscle

During PIR technique of soleus muscle, each participant lied prone on the table with his knee positioned in 90 degrees of flexion. The therapist stood at the side of the table and passively performed dorsiflexion of the foot by pulling up the heel while pushing down the metatarsals. After reaching the barrier, the participant was directed to isometrically resist further dorsiflexion for ten seconds. After isometric contraction, the participant was directed to stop the resistance and relax. The relaxation phase was performed as long as free movement of the foot toward a new barrier was present. No passive stretching was applied during the relaxation phase. When there was no releasing phenomen present and the foot did not move freely anymore, the isometric contraction against the resistance of the therapist was repeated again. According to Lewit (2003) PIR technique was performed in three cycles by the same therapist (the author). Each participant was given an explanation of PIR technique and was told how he is expected to cooperate. The technique was chosen according to Liebenson (2007) and is presented in the figure number ten.

Figure nr. 10: PIR technique of the soleus muscle (Liebenson, 2007)

4.2.4 Myotonometric device

Palpation has been the most common but subjective method to assess a muscle tone. Therefore, an objective non-invasive quantitative measurement of the mechanical properties of the skeletal muscle tone is needed for a better understanding of the role of these properties in neuromuscular and musculoskeletal physiology. Muscle is described as a material having viscoelastic properties. The myotonometric device represents the non-invasive device that is able to measure muscle tonus in state of alertness and under neuromuscular control (Šifta, 2005; Viir et al., 2006).

According to Viir et al. (2006) the myometric device offers the possibility to measure in vivo, non-invasively and simultaneously three parameters. This fact presents the principle difference between myometry and any other mode of measuring skeletal muscle tone.

Myotonometer measures:

- the natural oscillation frequency which characterizes muscle tension,
- the stiffness, as the ability of the muscle to resist changes in shape, and
- the logarithmic decrement of damping which characterizes muscle elasticity.

4.2.4.1 Characteristics of the myotonometric device

In this chapter the myotonometric device used in this study will be described. The fundamental part of the device is tensiometric sensor that is, together with the measuring tip, attached to the moving arm. The measuring tip, with an area of 3,7 cm^2 (the area is significant with the area of a thumb), is placed perpendicularly to the muscle being measured. Furthermore, it moves at the constant velocity of 3,5 – 4 mm/s with linear deviation at 3% into the examined muscle and back to determine the resistance of the tissue. The myotonometer does not pass through the skin surface. The measuring tip is powered by the stepper motor within the distance of 32 mm in both directions. It is necessary to manually switch the direction of the measuring tip from going toward the muscle belly to going away from the muscle belly (Šifta, 2005, et al. 2009).

The schema of the myotonometer is presented in the figure number eleven.

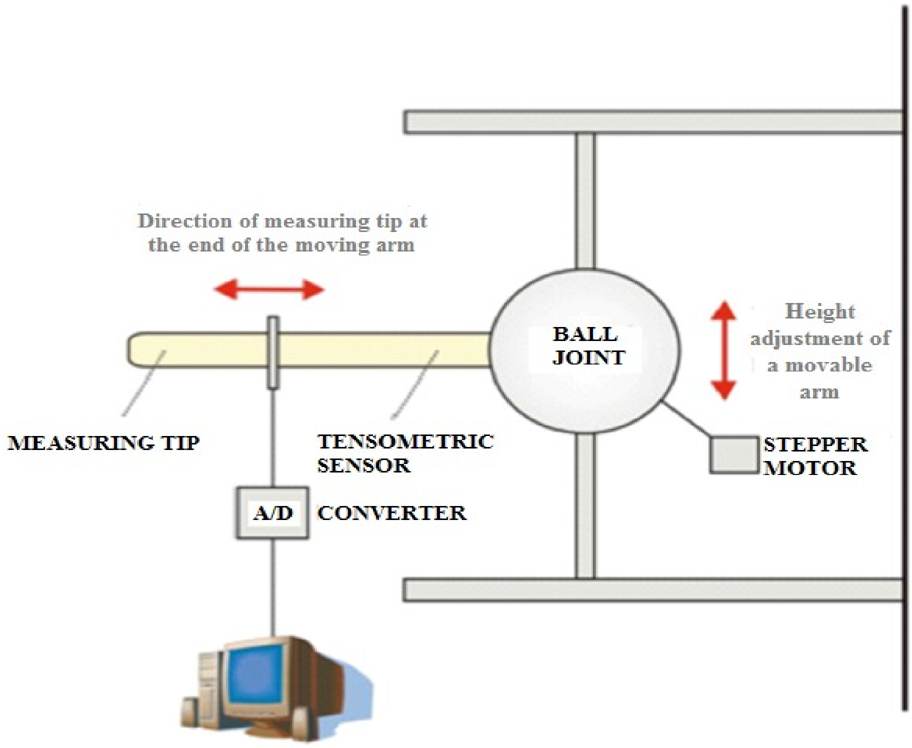


Figure nr. 11: Schema of myotonometer [translated from Czech language (Šifta, 2005)]

The tensiometric sensor and two eight-bit A/D amplifiers for (monitoring) force and distance form the electronic part of the myotonometric device. The myotonometric device is serially connected to the computer (a standard IBM PC). The tensiometric sensor within the measuring tip is connected to the resistive sensor for distance. The monitored distances are converted and further processed in special software in Matlab program, so the final shape of the hysteresis curve can be obtained. The hysteresis curve represents the viscoelastic properties of the examined muscle (Šifta, 2005, et al. 2009).

It is possible that during the ten seconds long period of measuring time, the measuring tip does not manage to move throughout the entire distance and so an incomplete hysteresis loop would be obtained (Šifta, 2005, et al. 2009).

4.2.4.2 Process of measurement

The process of measuring as well as the data analysis were based on the previous studies of Šifta (2005, et al. 2009).

In order to measure soleus muscle in its relaxed state, the participants lied prone on the table and the tested lower extremity was placed on a pillow to reach a slight flexion in the knee joint. We made sure that the tested lower extremity will not move during the measurement. This position enables palpation of soleus muscle and so it represents the ideal position for myotonometric measurement.

Soleus muscle was chosen for this measurement. Prior to each measurement, the measuring tip of the myotonometer was located properly to point perpendicularly to the center of the muscle belly. The duration of the impact was set at 10 ms, after which the response of the muscle tissue was recorded. Each measurement of soleus muscle was performed twice (Šifta, 2005, et al. 2009).

4.2.4.3 Data interpretation

As it was mentioned earlier, the hysteresis curve represents the viscoelastic properties of the muscle. Several parameters can be observed at the hysteresis curve. The two most important parameters are the increase value and the deflection value of the curve. The parameter of increase value describes the muscle tonus (stiffness) and the muscle deflection represents the muscle elasticity (Šifta, 2005).

The hysteresis curve has an ascending and descending part. The lower and upper limit is set for the further calculations. The lower limit is set with the value of 10N and the upper limit is dependent on the character of hysteresis curve and it could reach the value of 40N. These two limits are connected by the secant line that represents the slope of the curve. The point, where the secant line is the farthest from the ascending part of the hysteresis curve, is drawn a perpendicular line. The lenght of this line is directly proportional to the deflection value of the hysteresis curve. The dissipation of the energy can be also calculated out from the hysteresis curve, but for technical reasons this parameter was not included in our study (Šifta, 2005).

The ilustration of the hysteresis curve including all the parameters is illustrated bellow in the figure number twelve.

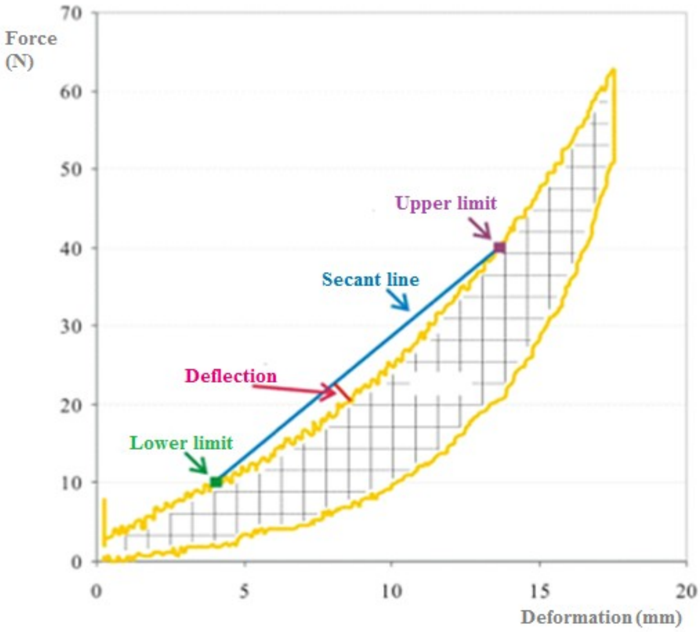


Figure nr. 12: The description of hysteresis curve [translated from Czech language (Šifta, 2005)]

4.3 Data analysis

The results from the Wingate test were processed in the Biomedical Laboratory at UK FTVS. The results contained additional parameters including lactate level, BMI index, heart rate and parameters describing performance as mean power, maximal and minimal power and revolutions.

Data from myotonometric measurements were at first put from MS DOS to Microsoft Office Excel. Final results were obtained in special software in Matlab program including hysteresis curves and two important parameters for further analysis such as the increase value and the deflection value. Graphs were chosen to represent these processes as they had better quality in representing the viscoelastic properties of experimental and control lower extremities.

5 RESULTS AND DISCUSSION

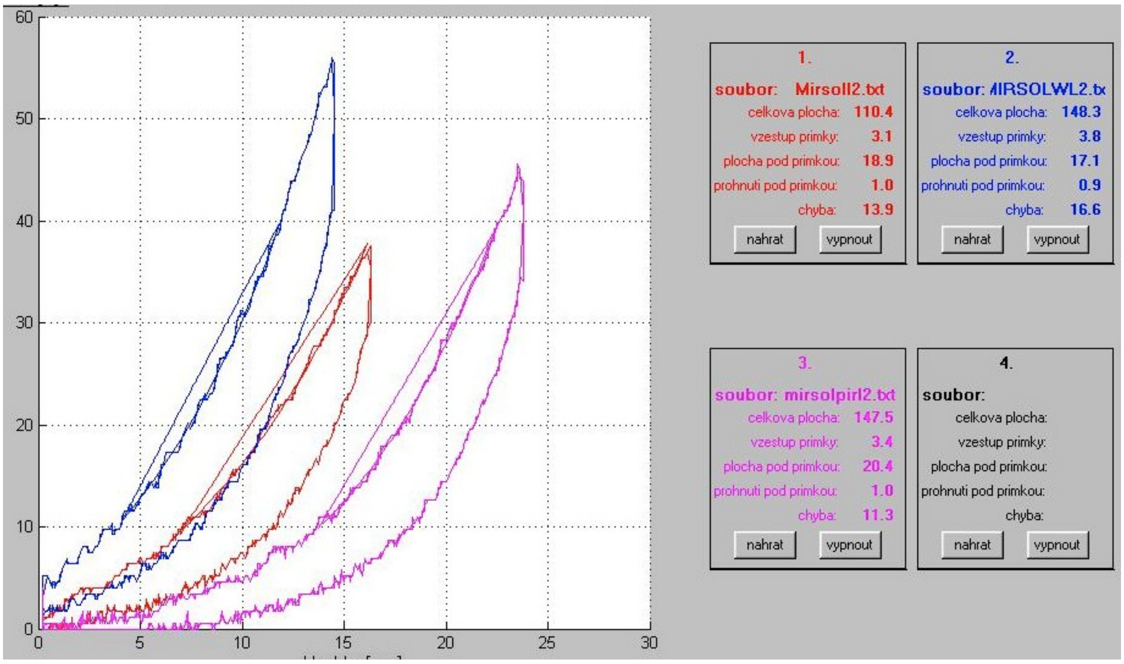
The results of each participant are presented in three major chapters. First chapter includes the results of the Wingate test. Second chapter includes graphs and tables representing the results obtained from the myotonometric measurements of the experimental lower extremity and third chapter also includes the graphs and tables obtained from the myotonometric measurements but of the control lower extremity. Values obtained in the myotonometric measurements are demonstrated without units according to Šifta (2012).

As stated by Šifta (2005) with regard to the measuring with a myotonometric device, the viscoelastic properties of a muscle can be objectively measured and also described with the hysteresis curve graph. There are two main parameters used todescribe muscle stiffness and muscle elasticity; the first parameter is the increase of the curve and the second is the deflection of the curve. The first parameter describes the muscle stiffness; the higher the stiffness of the muscle the more pathological the muscle is. The second parameter, deflection of the curve, represents the muscle elasticity; the higher is this parameter, the more elastic and so the "healthier" the muscle is.

Below in the graph number one, I present the ideal changes of the hysteresis curve of an experimental soleus muscle during all three measurements. These changes were expected according to our hypotheses. The first of the two important parameters, the increase value, was expected to be low after the first measurement and it was expected to increase after the Wingate test. The third measurement after the application of PIR technique on the soleus muscle was expected to show a decrease of this parameter. In other words, the stiffness of the muscle was expected to be lower after the first measurement and higher after the second measurement following the physical activity. Muscle stiffness was expected to be lower again after PIR. The second parameter, representing muscle elasticity, the deflection value, was expected to be higher after the first measurement. The elasticity should decrease after the physical activity and increase again after PIR.

The graph number one demonstrates three hysteresis curves. The red color represents the hysteresis curve before the WT. The blue color represents the shape of the hysteresis curve after the WT and the pink colored hysteresis curve is representing the properties of the muscle after PIR.

Graph Nr. 1: Expected hysteresis curve representing all three measurements (own results)



At the end of this chapter is the summary of results and discussion with evaluation of the three hypotheses included.

5.1 Review of the results

5.1.1 Wingate test results

The restults of the Wingate test are shown in the table number three. Each number represents a particular participant. The results of the Wingate test are described with four parameters as mean power, revolutions, heart rate and lactate level; the later two, the heart rate and the lactate level belong to additional indicators.

Table nr. 3: Wingate test results (own results (OR)):

Participant nr.	1	2	3	4	5	6
Mean Power (W/kg)	7,3	8,0	8,2	5,6	6,2	7,8
Revolutions (during test)	43,6	39,8	48,7	33,5	38,8	46,5
Heart Rate (after test)	111	152	180	187	176	177
Lactate Level (mmol/l)	7,4	8,5	6,1	6,5	7,2	9,7

5.1.2. Results from myotonometric measurements of the experimental lower extremity - PIR

Participant number one

Graph nr. 2: Results of P.nr. 1-E (OR)

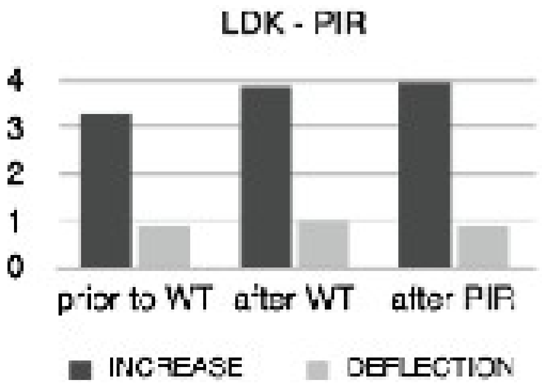


Table nr. 4: Results of P.nr. 1-E (OR)

LDK - PIR		
Prior to WT	**After WT**	**After PIR**
3,3	3,9	4,0
0,9	1,0	0,9

The results of the first participant obtained in the measurement of the experimental lower extremity are presented in the graph number two and table number four. After WT the muscle stiffness increased by 0,6 and increased again after PIR by 0,1. Muscle elasticity increased by 0,1 after WT and decreased by 0,1 after PIR.

Participant number two

Graph nr. 3: Results of P.nr. 2-E (OR)

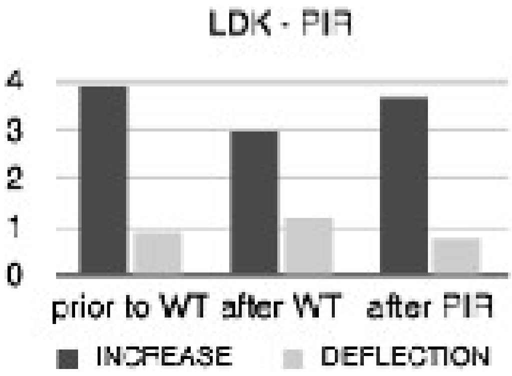


Table nr. 5: Results of P.nr. 2-E (OR)

LDK - PIR		
Prior to WT	**After WT**	**After PIR**
3,9	3,0	3,7
0,9	1,2	0,8

The results of the second participant obtained in the measurement of the experimental lower extremity are presented in the graph number three and table number five. The muscle stiffness after the WT was lower by 0,9 than prior to WT and muscle elasticity increased by 0,3 after the WT. After PIR muscle stiffness increased by 0,7 and muscle elasticity decreased by 0,4. The muscle stiffness prior to WT was higher than after PIR by 0,2, but elasticity of the muscle decreased by 0,1.

Participant number three

Graph nr. 4: Results of P. nr. 3-E (OR)

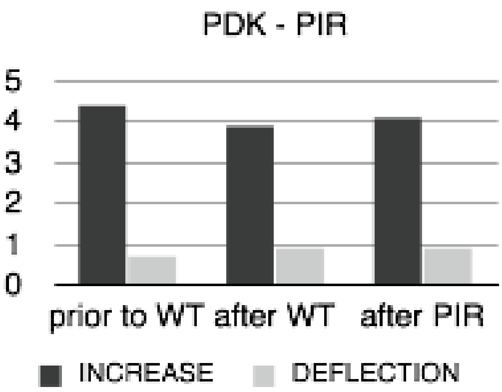


Table nr. 6: Results of P.nr. 3-E (OR)

PDK - PIR		
Prior to WT	**After WT**	**After PIR**
4,4	3,9	4,1
0,7	0,9	0,9

The graph number four and the table number six present the results obtained in the measurement of the experimental lower extremity of the participant number three.

The increase value decreased after the WT by 0,5 and increased by 0,2 after PIR. Muscle elasticity increased after WT by 0,2 and remained on this level after PIR.

Participant number four

Graph nr. 5: Results of P.nr. 4-E (OR)

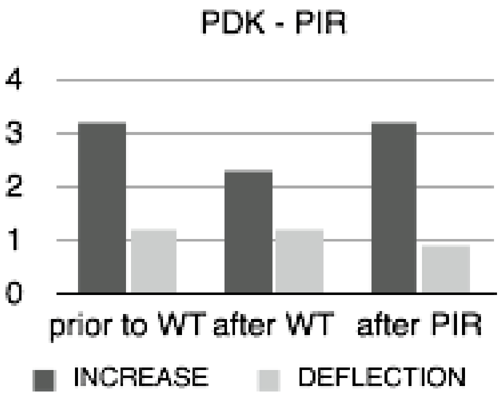


Table nr. 7: Results of P.nr. 4-E (OR)

PDK - PIR		
Prior to WT	**After WT**	**After PIR**
3,2	2,3	3,2
1,2	1,2	0,9

As we can see in the graph number five and the table number seven, the muscle stiffness has the same value for both measurements before WT and after PIR. The muscle was less stiff after WT, when the increase value decreased by 0,9. The muscle elasticity has the same value for the first and second measurement. A decrease of muscle elasticity by 0,3 occurred after PIR.

Participant number five

Graph nr. 6: Results of P.nr. 5-E (OR)

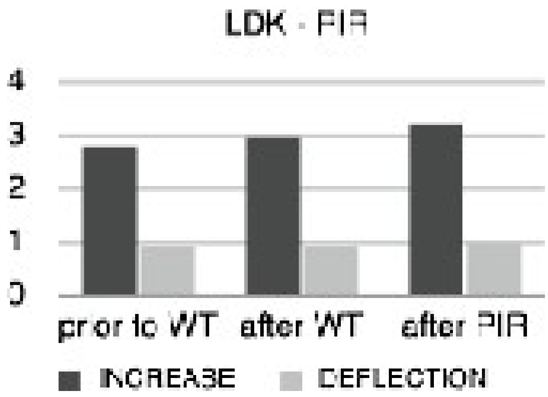


Table nr. 8: Results of P.nr. 5-E (OR)

LDK - PIR		
Prior to WT	**After WT**	**After PIR**
2,8	3,0	3,2
0,9	0,9	1,0

The stiffness of the muscle was higher after WT by 0,2 and after the PIR increased by 0,2. After PIR the muscle elasticity was higher than prior to and after WT by 0,1. These changes can be seen in the graph number six and in the table number eight.

Participant number six

Graph nr. 7: Results of P.nr. 6-E (OR)

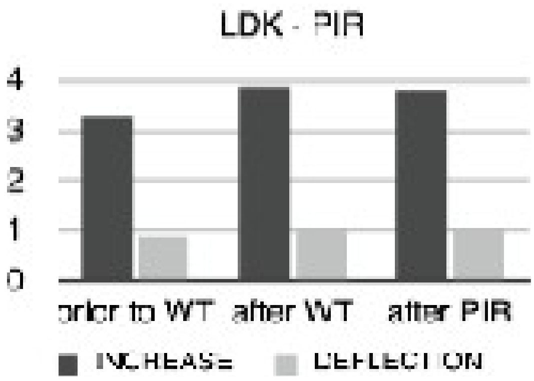


Table nr. 9: Results of P.nr. 6-E (OR)

LDK - PIR		
Prior to WT	**After WT**	**After PIR**
3,3	3,9	3,8
0,9	1,0	1,0

In the graph number seven and the table number nine it is shown that muscle stiffness increased after WT by 0,6. A decline by 0,1 occurred after PIR. The elasticity of the muscle increased by 0,1 after WT and remained the same also after PIR.

5.1.3 Results from myotonometric measurements of the control lower extremity - REST

Participant number one

Graph nr. 8: Results of P.nr. 1-C (OR)

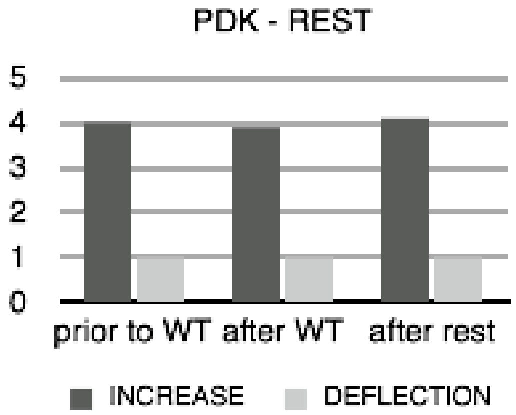


Table nr. 10: Results of P.nr. 1-C (OR)

PDK - REST		
Prior to WT	**After WT**	**After PIR**
4,0	3,9	4,1
1,0	1,0	1,0

The results of the first participant measured on the control lower extremity are presented in the graph number eight and in the table number ten. Muscle stiffness decreased by 0,1 after WT and then increased by 0,2 after resting. The elasticity of the muscle remained 1,0 for all three measurements.

Participant number two

Graph nr. 9: Results of P.nr. 2-C (OR)

Table nr. 11: Results of P.nr. 2-C (OR)

PDK - REST		
Prior to WT	**After WT**	**After PIR**
3,9	4,1	4,6
0,7	0,9	0,9

After WT the stiffness of the soleus muscle increased by 0,2 and after rest it increased by 0,5. Muscle stiffness was higher after the rest by 0,7 than prior to WT. The elasticity of the muscle also increased as stiffness increased after the WT by 0,2 and remained on the level of 0,9 after rest. The presentation of the results obtained from the measurement of the control lower extremity of the participant number two is presented in the graph number nine and table number eleven.

Participant number three

Graph nr. 10: Results of P.nr. 3-C (OR)

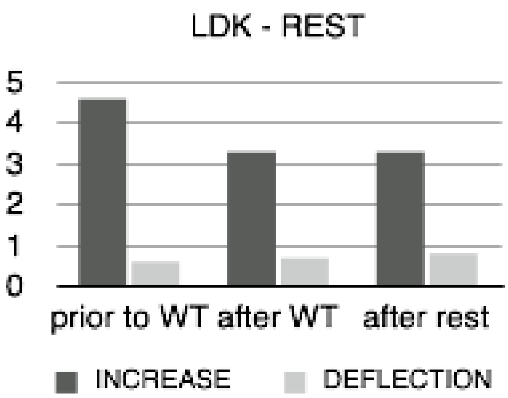


Table nr. 12: Results of P.nr. 3-C (OR)

LDK - REST		
Prior to WT	**After WT**	**After PIR**
4,6	3,3	3,3
0,6	0,7	0,8

According to the graph number ten and the table number twelve the stiffness of the muscle decreased after WT by 1,3 and this value remained constant after rest.

The elasticity of the muscle increased after WT by 0,1 and also increased by 0,1 after rest. The muscle stiffness was lower after rest than prior to WT by 1,3 and muscle elasticity was higher after rest by about 0,2 than prior to WT.

Participant number four

Graph nr. 11: Results of P.nr. 4-C (OR)

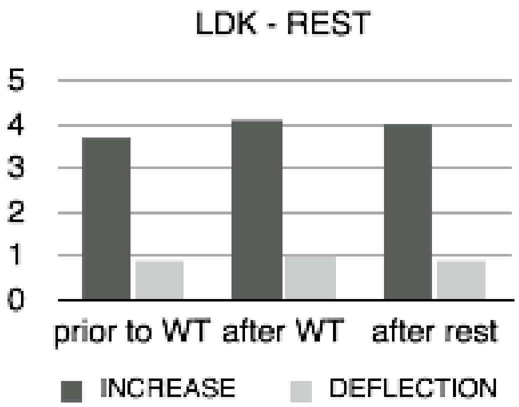


Table nr. 13: Results of P.nr. 4-C (OR)

LDK – REST		
Prior to WT	**After WT**	**After PIR**
3,7	4,1	4,0
0,9	1,0	0,9

The results of the control lower extremity of the participant number four are presented in the graph number eleven and the table number thirteen. After WT, muscle stiffness increased by 0,4 and after rest decreased by 0,1. Elasticity of the muscle increased after WT by 0,1 and after rest decreased back to the initial level of 0,9.

Participant number five

Graph nr. 12: Results of P.nr. 5-C (OR)

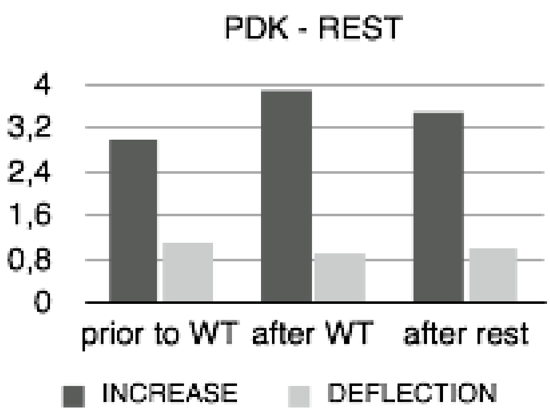


Table nr. 14: Results of P.nr. 5-C (RO)

PDK - REST		
Prior to WT	**After WT**	**After PIR**
3,0	3,9	3,5
1,1	0,9	1,0

As the muscle stiffness increased by 0,9 after WT, the elasticity of the muscle decreased by 0,2. After rest, muscle stiffness decreased by 0,4 and muscle elasticity increased by 0,1. Muscle stiffness is shown to be higher after rest than it was prior to WT for 0,5. All the changes of the stiffness and elasticity of the control lower extremity of the participant number five can be seen in the graph number twelve and the table number forteen.

Participant number six

Graph nr. 13: Results of P.nr. 6-C (OR)

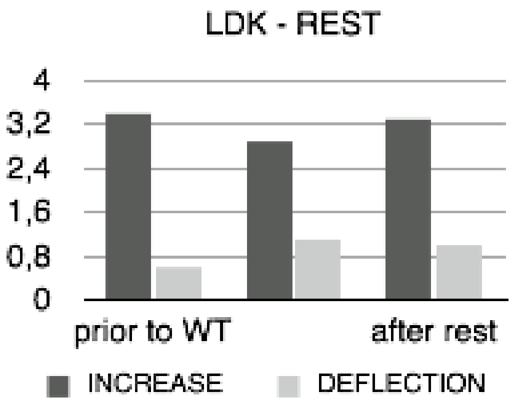


Table nr. 15: Results of P.nr. 6-C (OR)

LDK - REST		
Prior to WT	**After WT**	**After PIR**
3,4	2,9	3,3
0,6	1,1	1,0

The results of control lower extremity of the sixth participant are presented in the graph number thirteen and the table number fifteen. The stiffness of the muscle decreased after WT by 0,5 and increased after rest by 0,4. The stiffness of the muscle is 0,1 lower after rest than prior to WT. Elasticity of the muscle was the highest after WT, where it was 0,5 higher than prior to WT. After rest the elasticity of the muscle was lower then after WT by 0,1 and still by 0,4 higher than in the beginning.

5.2 Results summary

This chapter presents the summary of the results. For better understanding in the values measured in this experiment and thus for better understanding in results obtained in measurements of experimental and control lower extremity, six tables summarazing the values of two important parameters are provided. Below each table summarizing the values, there is a table demonstrating mean value, mean increase, mean decrease and percentage derived from changes of the values.

The first three summarizing tables describe the results of increase values representing muscle stiffness for experimental and control lower extremity. The first table shows changes of muscle stiffness prior to WT and after WT. The second table shows the changes of increase values after WT and after PIR or rest. The third table shows the increase values prior to WT and after PIR to compare the initial and the final values. The next three summarizing tables present the values of deflection describing changes of muscle elasticity during all three measurements and also comparing the experimental and control lower extremities.

For better understanding in the results obtained in this study, values of mean value, mean increase, mean decrease and percentages were calculated. Values were rounded to tenths. In accordance with the three hypotheses of this study, the percentage values are presented regarding the change that was expected in the particular hypothesis. For example stiffness of the muscle represented by the increase value was expected to increase after WT, thus there is a percentage value representing the increase of muscle stiffness (% (+)). After PIR stiffness was expected to decrease and the percentage value in the table represents the value of decrease of the increase value (% (-)). Muscle elasticity was expected to behave in the opposite to muscle stiffness and the percentage represents the expectations according to the hypotheses of this study.

It may be challenging to compare both measured soleus muscles because in most participants the values for each muscle differ in the initial value. Of course the viscoelastic properties of the takeoff lower extremity were expected to differ than the viscoelastic properties of the second lower extremity. This fact complicates the effort to make any conclusions from the results.

Table nr. 16: Increase values summary prior to WT and after WT for experimental and control lower extremity (own results)

	PIR – Experimental			Rest - Control		
Participant nr.	**Prior to WT**	**After WT**	**Change +/-**	**Prior to WT**	**After WT**	**Change +/-**
1	3,3	3,9	+0,6	4,0	3,9	-0,1
2	3,9	3,0	-0,9	3,9	4,1	+0,2
3	4,4	3,9	-0,5	4,6	3,3	-1,3
4	3,2	2,3	-0,9	3,7	4,1	+0,4
5	2,8	3,0	+0,2	3,0	3,9	+0,9
6	3,3	3,9	+0,6	3,4	2,9	-0,5

Table nr. 17: Results overview, mean value and percentage of increase value prior to and after WT (own results)

	Mean increase (+)	**Mean decrease (-)**	**Mean value**	**% (+)**
WT-E	0,5	0,8	-0,2	50
WT-C	0,5	0,6	-0,1	50
TOTAL	0,5	0,7	-0,1	50

The first hypothesis was expecting the stiffness of the muscle to increase after the Wingate test. As we can see in the table number sixteen and seventeen, the stiffness of soleus muscle increased in 50% of participants. The mean value shows a decrease of the muscle stiffness by 0,1 in both lower extremities.

Table nr. 18: Increase values summary after WT and after PIR or rest (own results)

	PIR - Experimental			Rest - Control		
Participant nr.	**After WT**	**After PIR**	**Change +/-**	**After WT**	**After rest**	**Change +/-**
1	3,9	4,0	+0,1	3,9	4,1	+0,2
2	3,0	3,7	+0,7	4,1	4,6	+0,5
3	3,9	4,1	+0,1	3,3	3,3	0
4	2,3	3,2	+0,9	4,1	4,0	-0,1
5	3,0	3,2	+0,2	3,9	3,5	-0,4
6	3,9	3,8	-0,1	2,9	3,3	+0,4

Table nr. 19: Results overview, mean value and percentage of increase value after WT and after PIR or rest (own results)

	Mean increase (+)	**Mean decrease (-)**	**Mean value**	**% (-)**
PIR	0,4	0,1	+0,3	17
REST	0,4	0,3	+0,1	34

The increase values representing muscle stiffness were expected to decrease after PIR or rest, and more after PIR. According to the results of experimental soleus muscle after PIR presented in the table number eighteen and nineteen, the stiffness of the muscle decreased in 17% of participants. The increase value decreased only with the sixth participant. The muscle stiffness of the control soleus muscle decreased in 34% of participants. The mean value representing muscle stiffness after PIR shows an increase of the increase value for 0,3 and in comparison, the mean value for muscle stiffness after rest shows an increase of the increase value for 0,1.

Table nr. 20: Increase values summary, comparing experimental and control lower extremity after first and third measurement (own results)

	PIR – Experimental			Rest - Control		
Participant nr.	**Prior to WT**	**After PIR**	**Change +/-**	**Prior to WT**	**After rest**	**Change +/-**
1	3,3	4,0	+0,7	4,0	4,1	+0,1
2	3,9	3,7	-0,2	3,9	4,6	+0,7
3	4,4	4,1	-0,3	4,6	3,3	-1,3
4	3,2	3,2	0	3,7	4,0	+0,3
5	2,8	3,2	+0,4	3,0	3,5	+0,5
6	3,3	3,8	+0,5	3,4	3,3	-0,1

Table nr. 21: Results overview, mean value and percentage of increase value prior to WT and after PIR or rest (own results)

	Mean increase (+)	**Mean decrease (-)**	**Mean value**	**% (-)**
PIR	0,5	0,3	0,2	34
REST	0,4	0,7	0	34

The tables, number twenty and twenty-one are presented as an overview of the muscle stiffness prior to the experiment and after PIR or rest. The increase value after PIR decreased in two participants (34%) and participant number four had the same level of muscle stiffness after PIR as he had prior to WT. The same amount of participants showed a decrease of muscle stiffness also after rest (34%). The mean increase demonstrates the increase value of the experimental lower extremity to increase more than the control lower extremity for 0,1 and the mean decrease shows the increase value to decrease more in the control lower extremity for 0,4. Mean values demonstrate the increase values to change on average for 0,2 in experimental lower extremity and the mean value for control lower extremity is 0. It means that the muscle stiffness increased on average for 0,2 after PIR and the muscle stiffness it did not change after rest.

The second participant is the only one with the same increase values of both soleus muscles prior to WT and thus it may be used for a proper comparison. However, the important part of WT is missing in this comparison. The increase value of the soleus muscle of the experimental lower extremity decreased after PIR by 0,2 in contrast with the increase value of the soleus muscle of control lower extremity that increased after rest for 0,7.

Table nr. 22: Deflection values summary, comparing experimental and control lower extremity prior and after WT (own results)

	PIR - Experimental			REST -Control		
Participant nr.	**Prior to WT**	**After WT**	**Change +/-**	**Prior to WT**	**After WT**	**Change +/-**
1	0,9	1,0	+0,1	1,0	1,0	0
2	0,9	1,2	+0,3	0,7	0,9	+0,2
3	0,7	0,9	+0,2	0,6	0,7	+0,1
4	1,2	1,2	0	0,9	1,0	+0,1
5	0,9	0,9	0	1,1	0,9	-0,2
6	0,9	1,0	+0,1	0,6	1,1	+0,5

Table nr. 23: Results overview, mean value and percentage of increase value prior to and after WT (own results)

	Mean increase (+)	Mean decrease (-)	Mean value	% (-)
WT-E	0,2	-	0,1	0
WT-C	0,2	0,2	0,1	17
TOTAL	0,2	0,2	0,1	17

The elasticity of the muscle was expected to decrease after WT. But as we can see in the table number twenty-two summarizing the values, the elasticity of the muscle decreased only in one soleus muscle of the control lower extremity. In three soleus muscles, two of the take-off lower extremity and one of the non-take-off extremity, remained without any change of the deflection value representing muscle elasticity. The elasticity of the soleus muscle decreased in 17% of participants as it is presented in the table number twenty-three.

Table nr. 24: Deflection values summary, comparing experimental and control lower extremity after WT and after PIR (own results)

	PIR - Experimental			Rest - Control		
Participant nr.	**After WT**	**After PIR**	**Change +/-**	**After WT**	**After rest**	**Change +/-**
1	1,0	0,9	-0,1	1,0	1,0	0
2	1,2	0,8	-0,4	0,9	0,9	0
3	0,9	0,9	0	0,7	0,8	+0,1
4	1,2	0,9	-0,3	1,0	0,9	-0,1
5	0,9	1,0	+0,1	0,9	1,0	+0,1
6	1,0	1,0	0	1,1	1,0	-0,1

Table nr. 25: Results overview, mean value and percentage of deflection value after WT and after PIR or rest (own results)

	Mean increase (+)	Mean decrease (-)	Mean value	% (+)
PIR	0,1	0,3	-0,1	17
REST	0,1	0,1	0	34

As was already described in the beginning of this chapter, the elasticity of the muscle is expected to increase after application of relaxation technique. According to the results of experimental lower extremity presented in the table number twenty-four, an increase of the deflection value can be presented only in participant number five (17%). The control lower extremity shows an increase of muscle elasticity in two participants (34%). Muscle elasticity did not change in two soleus muscles of the experimental lower extremity and also in two soleus muscles of the control lower extremity. The mean decrease shown in the table number twenty-five demonstrates a higher decrease of muscle elasticity after PIR by 0,2. The mean value also presents a higher decrease in soleus muscle of the experimental lower extremity by 0,1.

Table nr. 26: Deflection values summary, comparing experimental and control lower extremity prior to WT and after PIR or rest (own results)

	PIR – Experimental			Rest – Control		
Participant nr.	**Prior to WT**	**After PIR**	**Change +/-**	**Prior to WT**	**After rest**	**Change +/-**
1	0,9	0,9	0	1,0	1,0	0
2	0,9	0,8	-0,1	0,7	0,9	+0,2
3	0,7	0,9	+0,2	0,6	0,8	+0,2
4	1,2	0,9	-0,3	0,9	0,9	0
5	0,9	1,0	+0,1	1,1	1,0	-0,1
6	0,9	1,0	+0,1	0,6	1,0	+0,4

Table nr. 27: Results overview, mean value and percentage of increase value prior to WT and after PIR or rest (own results)

	Mean increase (+)	**Mean decrease (-)**	**Mean value**	**% (+)**
PIR	0,1	0,2	0	50
REST	0,3	0,1	0,1	50

The table number twenty-six serves again as an overview of the elasticity of the soleus muscle elasticity after the first measurement and after the third measurement of experimental and control lower extremity. The deflection value was expected to be higher after PIR or rest as the elasticity is expected to be higher after relaxation of the muscle. This value increased in three participants after PIR (50%) and three participants after rest (50%). Mean value shown in the table number twenty-seven demonstrates the increase of muscle elasticity after rest to be higher by 0,1 than after PIR.

5.3 Discussion

The aim of this study was to measure viscoelastic properties of the muscle prior to and after the application of PIR technique. PIR technique is a common physiotherapeutic method used in everyday practice. As can be seen in the chapter summarizing the results, the obtained results are very inconsistent; althought, this could have been expected from a pilot study with six participants. In the results summary, a change of the values by 0,1 can be frequently found. This change cannot be accepted as significant, because it could represent a deviation in measurement.

Participants were chosen randomly and are without any disorder or disease. Participants represented a homogenous group for this study, although a higher number of participants is needed in further studies to obtain more significant results.

The answers to the hypotheses of this study were derived from the results of the increased value representing muscle stiffness. This value is, according to Šifta (2012), more appropriate to describe changes of the muscle properties because the values of this parameter are closer to the structure of the muscle.

The first hypothesis, anticipating muscle tonus to increase after the WT, was not definitely confirmed. Muscle stiffness increased in 50% of participants. As can be seen in the table number sixteen and seventeen, stiffness of soleus muscle of takeoff lower extremity increased in 50% and decreased in 50% in compliance with the results of the control lower extremity. The decrease of muscle tonus after the wingate test could also be caused by the change in the parasympathetic nervous system. This change resulted as the stress that was present prior to the test was now removed. WT lasted for thirty seconds and we presume that it was too short a physical activity to increase muscle tonus. During WT the trophic and tropic effects improved and thus the muscle was filled with liquid component. The time period of WT was also not long enough to carry the liquid components away from the muscle. The presence of this component caused the decrease of muscle tonus, because it leads to an increase of the level of the viscous component of the muscle and this leads to a decrease of the muscle hysteresis. The fact that the first hypothesis was not confirmed, because muscle tonus did not increase after WT, had an influence on the confirmation process of hypothesis number two and three.

Hypothesis number two, expecting muscle tonus to decrease after PIR was also not confirmed. According to the results shown in table number 18, the muscle stiffness decreased in one participant. This hypothesis cannot be objectively evaluated, because PIR was not applied on a hypertonic muscle. The efficacy of PIR technique in decreasing muscle tonus was proved in one participant (17%). Mean value, shown in the table number nineteen, was calculated from the changes of all increased values of the experimental lower extremity and came out as a value of 0,3. It means that the mean value of muscle stiffness has not decreased, but it has increased on average by 0,3 after PIR.

The third hypothesis, expecting the control lower extremity to have higher muscle tonus than the experimental lower extremity, was also not confirmed. According to the results, the stiffness of the muscle decreased in 17% of participants after PIR and in 34% of participants after rest. According to the table number nineteen, the mean decrease calculated for the increase value of the experimental lower extremity shows a decrease of 0,1. In comparison, the mean decrease calculated for control lower extremity shows a decrease of the increase value of 0,3. It means that the mean decrease of the muscle stiffness after rest was higher by 0,2. Also, a mean value was calculated for these two lower extremities. Mean value, representing the change of the increase value, was shown to increase on average of 0,3 in experimental lower extremity and to increase on average of 0,1 in control lower extremity. Regarding mean values, it can be stated that the muscle stiffnes increased on average by 0,2 more after PIR than after rest.

Due to the percentage values of the results and frequent changes of the values by 0,1, no definite conclusion can be made regarding the efficacy of PIR technique on muscle tonus after physical activity.

Some of the results show that the muscle tonus was increased already before WT. This situation could be explained by the stress of the participant before measuring process. Under stressful conditions, the human's body is preparing for action and muscles are supplied with blood. In addition, the basal level of muscle tension could be changed.Themyotonometric device is a new device so the stress could be even higher than prior to measuring with familiar devices. Due to an obligation to inform participants about the upcoming experiment, they knew that they were about to partake in a physical test. All these factors could lead to an increase of the basal muscle tone.

The Wingate test was performed in its original version; thirty seconds of cycling on a bicycle ergometer. During thirty seconds of cycling, the blood circulation is facilitated and the muscle warmed up. Also the recovery from stress after performing the physical demanding test could be an explaination for the decrease of the muscle tonus after WT. There was an increase of lactate level concentration after WT, but the physical activity may have been too short to cause an increase of tonus of soleus muscle. Some variations in the cyclying activity between participants could also have occurred. Although, cycling is a simple activity familiar to all participants it may vary between individuals as gait or running have many variations of performance. Participants could develop a variety of forces while pedaling with their forefoot, heel or center of the foot. The position of the foot has an impact on higher structures such as knee and hip and therefore the involvement of muscle groups can be altered. In order to develop as much force as possible, participants were allowed to pedal in a standing position. This method of pedaling probably led to higher power output. Conversely, it could have altered the involvement of muscles of the lower extremities; they may “assist” with the muscles of the trunk instead of putting greater effort into pedalling “only” as they would if cyclying was done while seated. We can assume that WT was not an ideal physical activity leading to increasing muscle tonus. I would be interested in choosing a different physical test with a longer time period of physical activity and examine if it would lead to an increase of stiffness of the muscle.

PIR technique was performed three times with a 10 seconds long contraction phase and a relaxation phase as long as the free movement toward a new position was present. The technique was performed according to Liebenson (2007). But still it isa technique performed by a physiotherapist and not any device thus a human error might occur during the performance. Also there was a tendency to reach optimal level of muscle force developed by the participant. Because there was no computer to give feedback about the force of resistance developed by the therapist, it also might have led to an inaccurate performance of PIR technique. Another fact could be a lack of experience of the therapist. For further research, it would be worth thinking about these factors and try to find an optimal solution to overcome the mentioned challenges. According to Lewit (2003) it is the number of repetitions optimal when performed for three or five times. For further research it may be interesting to find if the properties of the muscle tissue would change when a higher number of PIR repetitions would be applied. Another suggestion would be to measure the soleus muscle again in an hour and observe whether the two parameters would change.

The isometric contraction included in PIR may explain the increasing muscle stiffness that has occured after application of PIR in 80% of patients and decreasing muscle elasticity in 80% after PIR. After WT the muscle was probably warmed up and the blood circulation was facilitated while during the contraction phase of PIR, the increase of muscle stiffness may be caused by accumulation of blood in the muscle. This isometric contraction of soleus muscle is the difference between PIR and rest.

The myotometric device used for this thesis was developed by Šifta and also operated by Šifta. While measuring the muscle tonus, we made sure to precisely localize the center of soleus muscle belly and to place the myotonometric device in that position to get as precise values as possible. The experimental lower extremity was put in to fix position so as not to slip away from the measuring tip. Each measuring of the soleus muscle was performed twice therefore obtained data can be expected to be in compliance with the real viscoelastic properties of the muscle. Still, there is a need to manually switch the course of the measuring tip from heading to the muscle belly to heading out of the muscle belly. Although the manual switch of the course could lead to some deviation in the measurement, this fact remains the same for all measurements performed on the myotonometric device that is in most situations operated by Šifta himself. This means that obtained data were all measured under the same conditions and thus, there is a stability of measured results between the studies measured on this device (Šifta, 2005).

The increase value and the deflection value were used to describe the parameters of the hysteresis curve; although, for complete and correct interpretation of viscoelastic properties of the muscle, it is necessary to observe overall character and shape of the hysteresis curve. Important to mention is the content of hysteresis curve, which is determined by the energy dissipation. For technical reasons it was not possible to determine this parameter (Šifta, 2005).

Another interesting finding can be deduced out of the results regarding the muscle elasticity to be neither directly or indirectly proportional to stiffness of the muscle. Although this finding was already mentioned and confirmed in the thesis written by Dastych (2011). Muscle elasticity was expected to decrease as the muscle stiffness increases and vice versa. When the elasticity of the muscle increases and the stiffness of the muscle decreases, the muscle is considered to be healthier. Soleus muscle was expected to become healthier after PIR, although, elasticity of the muscle increased in 67% after WT.

As the values of stiffness and elasticity of the muscle differ prior to WT, the properties of muscle tissue differ as well. Each muscle can be measured to be fatter, more fibrous or muscle (Šifta et al., 2009). The thickness of the subcutaneous fat above the muscle may cause some uncertainty in the myotonometric measurements, though this is more significant if the fat is greater than 4,0 mm thick (Korhonen et al, 2005). This fact is important to consider in the results as well.

PIR technique was expected to decrease muscle tonus. Although, as it is explained in the paragraph about hypothesis number two, it is difficult to evaluate the effect of PIR technique on hypertonic muscle when it was not applied to the hypertonic muscle of 50% of participants. Thus, the efficacy of PIR technique cannot be considered as either positive or negative.

This thesis does not represent the first case, where the technique or procedure expected to decrease muscle tonus was not confirmed. For example in the thesis of Pavelková (2010) stretching of the muscle was not confirmed to decrease its tonus, but the results showed the opposite tendency of the muscle tonus. A similar situation was described in the thesis of Dastych (2011) where the sauna was not confirmed as a procedure that decreased muscle stiffness.

According to Lewit (2003) PIR leads to a decrease of muscle tonus as long as it is applied to a hypertonic muscle and in other cases fails. In this study PIR was applied on soleus muscle that belongs to a group of the postural muscles. Overload of the postural muscle mostly leads to formation of trigger points or a tendency to shorten. According to Lewit (2003) PIR is an ideal technique to use in muscles with a tendency to shorten. Due to decreasing the muscle tonus, the muscle is freer to move and a greater range of motion is obtained. In Lewit (2003) is also stated that PIR can be used to cure trigger points. This finding could be interesting to explore in further studies in a PhD program. The phasic muscles have a tendency to slacken. According to Šifta´s measurement (2012) of the efficacy of PIR on gastrocnemius muscle caput mediale, the results varying and were insignificant in decreasing tonus of hypertonic gastrocnemius muscle caput mediale. Regarding these findings and the results obtained in this study, I would like to continue to experiment on the efficacy of PIR. The first condition for further studies of PIR efficacy must be the appropriate physical activity that leads to an increase of muscle tonus of the tested muscle.

The myotonometer was already used in many other studies showing itself as a reliable device for measuring viscoelastic properties of skeletal muscle. The myotonometer has been shown to have excellent inter-observer repeatability and excellent intra-class correlations. There is a limitation of myotonometric measurement with regard to the measurement of deep muscles; as they are unreachable for palpation, they are unreachable for a myotonometric device (Bizzini et al., 2003; Šifta, 2005; Viir et al., 2006).

In Gavronski et al. (2007) are presented the possibilities of use of the myotonometric device. Myotonometric devices have been already used to establish the rigor mortis, to study the pathology of the muscle-neural complex and to measure the tissue tone of the soft palate in the patients with obstructive sleep apnoea syndrome. Other utilization of myotonometer can be to monitor the effectiveness of drug treatment (myorelaxants) and physiotherapy techniques. As well as the medical utilizations, it can be also used in athletes to predict readiness for resumption to sporting activities following “overtraining” or to observe the effects of immobilization (Bizzini et al., 2003). Šifta (2005) used the myotonometric device to measure the efficacy of botulotoxin treatment in spasticity.

Gavronski (2007) also mentions the measurements obtained from the myotonometric device to be in correlation with surface EMG measurement (expressed in the root mean square) and with the assessment scale of the resistance of extremity passive stress, modified Ashworth scale. Rätsep et al. (2011) used a myotonometric device to monitor rigidity in patients with Parkinson disease. He stated in his article that increased rigidity is associated with increased values of stiffness. Where the reliability and validity of the myotonometric device has been confirmed, its measurement results have been comparing to that of clinical UPDRS scores.

The great advantage of measuring muscle tonus with a myotonometric device is that there is no need of prior stretching, contracting, rotating, or vibration as is required for other methods such as the traditional quick release method, the resonant frequency method, or the method of magnetic resonance elastography. These deformations influence the viscoelastic properties of muscle tissue and exclude the possibility of measuring the tone of muscles in its initial relaxed state (Viir et al, 2006).

6 CONCLUSION

This pilot study,comparing two lower extremities of six participants demonstrates for the first time the measurement of PIR after physical activity on a myotonometric device developed by Šifta. The myotonometric device is, according to Šifta, an appropriate device for measuring viscoelastic properties of the muscle with remained control of central nervous system.

The two aims of this thesis were to measure the efficacy of PIR technique on viscoelastic properties of soleus muscle before and after physical activity using myotonometric device and also to summarize literature review regarding this topic.

The second aim of this thesis was to present a theoretical background regarding PIR and its mechanism of decreasing muscle tonus as was completed within the literature review. The literature review contains theoretical backgrounds about the physiology of MET developed by Mitchell and it also contains a description of PIR, the Lewit's technique. Another two modifications of MET were described in the chapter about MET. There is no definite explanation of the PIR mechanism yet; however the chapter regarding PIR contains the possible explanations for its mechanism according to the literature available. This summary represents the important part of the literature review because, in contrast with the description of PIR itself, the mechanism of decreasing muscle tonus is not as frequently contained in the literature available as the description of PIR.

Within the practical section of the thesis none of the three hypotheses were confirmed. The fact that the first hypothesis was not confirmed caused the second and third hypothesis to remain unconfirmed also. In order to evaluate efficacy of PIR, the tested muscle needs to be hypertonic prior to PIR. Unlike what was planned, PIR was not applied on hypertonic muscle and so the validity of the results is compromised.

The author does not make any conclusions regarding PIR having a positive or negative effect on decreasing muscle tonus. As this study is a pilot study, having six participants, and as neither of the hypotheses was confirmed, no conclusion considering efficacy of PIR can be made. Due to the fact that PIR is a frequently used technique in physiotherapy practice it would be interested to continue in further studies to attempt to objectively evaluate the efficacy of this relaxation technique. From my point of view, in further studies it would be worth including a higher number of participants who may all be athletes of one team, having the same amount of physical activity per week. I would expect these participants to have similar viscoelastic properties of muscle tissue and I would also expect athlete's soleus muscle to react more significantly than soleus muscle of non-regularly active participants. Also, the choice of a different physical activity prior to PIR would be worth considering.

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LIST OF ABBREVIATION IN THE TEXT

BMI - Body mass index

C – Control

CNS – Central nervous system

E – Experimental

EMG – Electromyography

FTVS – Fakulta tělesné výchovy a sportu

GTO – Golgiho tendon organs

Nr. – Number

OR – Own results

PIR - Post-isometric relaxation

PFS – Postfaciliation stretch

P.Nr. – proband number

RI – Reciprocal inhibition

UK – Univerzita Karlova

UPDRS – Unified Parkinson´s Disease Rating Scale

WT - Wingate test

LIST OF PICTURES IN THE TEXT

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LISTS OF ENCLOSURES

Enclosure nr. 1: Approval of the ethics committee FTVS UK, the original version

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Žádost o vyjádření etické komise UK FTVS

k projektu výzkumné diplomové práce, zahrnující lidské účastníky

Název: EFEKTIVITA TECHNIKY POSTIZOMETRICKÉ RELAXACE NA VISKOELASTICKÉ VLASTNOSTI SVALOVÉ TKÁNĚ PO FYZICKÉ AKTIVITĚ
(Efficacy of postisometric relaxation technique on muscle tissue and its viscoelastic properties after physical activity)

Forma projektu: Diplomová práce
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Popis projektu
Projekt bude uskutečněn v Kineziologické laboratoři UK FTVS. Jeho cílem je naměřit změny svalového napětí po aplikaci PIR na m.soleus pomocí přístroje Myotonometr. Projekt dohromady obsahuje 3 měření Myotonometrem. První měření bude provedeno před zahájením fyzické aktivity. Po fyzické aktivitě (Wingate test) následuje druhé měření a třetí měření bude provedeno po aplikaci metody PIR na testovanou dolní končetinu. Druhá dolní končetina poslouží jako končetina kontrolní.
Zajištění bezpečnosti pro posouzení odborníky:
Nebudou použity žádné invazivní techniky.
Etické aspekty výzkumu
V rámci tohoto měření jsou zahrnuti zdraví a aktivní jedinci v rozmezí 22-27 let. Postizometrická relaxace (PIR) představuje frekventovaně používanou fyzioterapeutickou metodu pro snížení svalového tonu. Provedené měření před a po aplikaci této metody nám pomůže ozřejmit vliv PIR na viskoelastické vlastnosti svalové tkáně a tedy i na svalový tonus daného svalu.
Informovaný souhlas (přiložen)

V Praze dne 13.2.2012 Podpis autora:

Vyjádření etické komise UK FTVS

Složení komise: Doc. MUDr. Staša Bartůňková, CSc.
Prof. Ing. Václav Bunc, CSc.
Prof. PhDr. Pavel Slepička, DrSc.
Doc. MUDr. Jan Heller, CSc.

Projekt práce byl schválen Etickou komisí UK FTVS pod jednacím číslem: 076/2012

dne: 17. 2. 2012

Etická komise UK FTVS zhodnotila předložený projekt a neshledala žádné rozpory s platnými zásadami, předpisy a mezinárodní směrnicemi pro provádění biomedicínského výzkumu, zahrnujícího lidské účastníky.

Řešitel projektu splnil podmínky nutné k získání souhlasu etické komise.

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razítko školy

podpis předsedy EK

Enclosure nr. 2: An informed consent of the participant, example

INFORMOVANÝ SOUHLAS

Byl(a) jsem osloven(a) studentkou navazujícího magisterského programu oboru Fyzioterapie na UK FTVS, Bc. Zuzanou Hlouškovou, abych se zúčastnil(a) měření v rámci její diplomové práce.

Byl(a) jsem obeznámen(a) s cílem tohoto měření, které se zabývá vlivem metody postizometrické relaxace na svalový tonus. Byl(a) jsem obeznámen(a), že měření svalového tonu bude provedeno pomocí přístroje Myotonometr a bude uskutečněno v prostorách Kineziologické laboratoře UK FTVS. Beru na vědomí, že předpokládaná doba měření je zhruba šedesát minut a měření bude provedeno jedenkrát v průběhu jednoho dne.

Jsem si vědom(a), že oba plánované postupy jako metoda postizometrické relaxace, tak i měření pomocí přístroje Myotonometr, představují neinvazivní metody. Byl(a) jsem obeznámen(a) s podstatou Wingate testu, který podstoupím před samotnou aplikací metody PIR. Byl(a) jsem informován(a) o bezbolestném průběhu měření, které může být provázeno jemným tlakem na oblast měřeného svalu v průběhu měření Myotonometrem.

Byl(a) jsem ujištěn(a) o diskrétním zacházením se získanými daty, které budou sloužit jen pro účely výše zmíněné diplomové práce.

V Praze dne........................ Jméno účastníka...

Podpis..